UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 18

CHAMPAIGN COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
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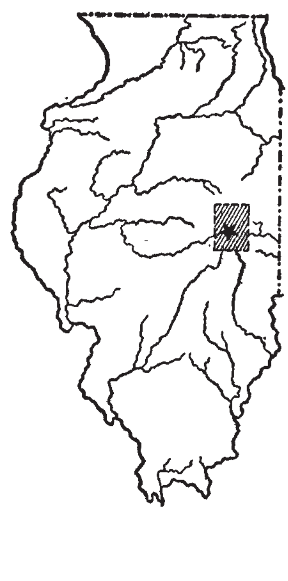


URBANA, ILLINOIS, NOVEMBER, 1918

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, subsequent reports are sent only to those on the mailing list who are residents of the county concerned, and to anyone else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles, in order to help the farmer and landowner understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports it will be found in the Appendix; but if necessary it should be read and studied in advance of the report proper.

CHAMPAIGN COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, E. VAN ALSTINE, AND F. W. GARRETT

Champaign county is located in the east-central part of Illinois, about 22 miles from the Indiana line and 140 miles from the north end of the state. The county is approximately 36 miles long and 27 miles wide, and contains 988 square miles, of which 99.7 percent, or all but three square miles, is tillable land. Not all of this tillable land, however, has been put under cultivation, some areas being still undrained or uncleared. In topography the land varies from flat to slightly rolling, with a few small areas along streams that are too steep to be cultivated. The difference in topography is due to two causes—glacial action and stream erosion.

Champaign county was covered by two ice sheets during the Glacial period. At that time snow and ice accumulated in the region of Labrador and to the west of Hudson Bay to such an amount that it pushed outward from these centers, especially southward, until a point was reached where the ice melted as rapidly as it advanced. In moving across the country, the ice gathered up all sorts and sizes of material, including clay, silt, sand, gravel, boulders, and even large masses of rock. Many of these materials were carried for hundreds of miles and rubbed against surface rocks or against each other until ground into sand and silt. When, thru the melting of the ice, the limit of advance was reached, this transported material accumulated in a terminal moraine, a broad undulating ridge, usually with a steep outer slope and with the inner slope longer and more gradual. The width of these moraines varies from a half mile to three or four miles. When the ice melted away more rapidly than the glacier advanced, the terminus of the glacier would recede and leave this material deposited somewhat uniformly over the area previously covered by the ice sheet. The glacier advanced and receded a number of times, and with each advance another moraine was formed. The intervening intermorainal tracts are now occupied chiefly by level, undulating, or slightly rolling plains.

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, et cetera, were mixed, and ground up together. This mixture of all kinds of material—boulders, clay, silt, sand, and gravel—is called boulder clay, till, glacial drift, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and this ice sheet may have been several thousand feet in thickness. The materials carried along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Preglacial ridges and hills were rubbed down, valleys were filled with the debris, and the surface features were changed entirely.

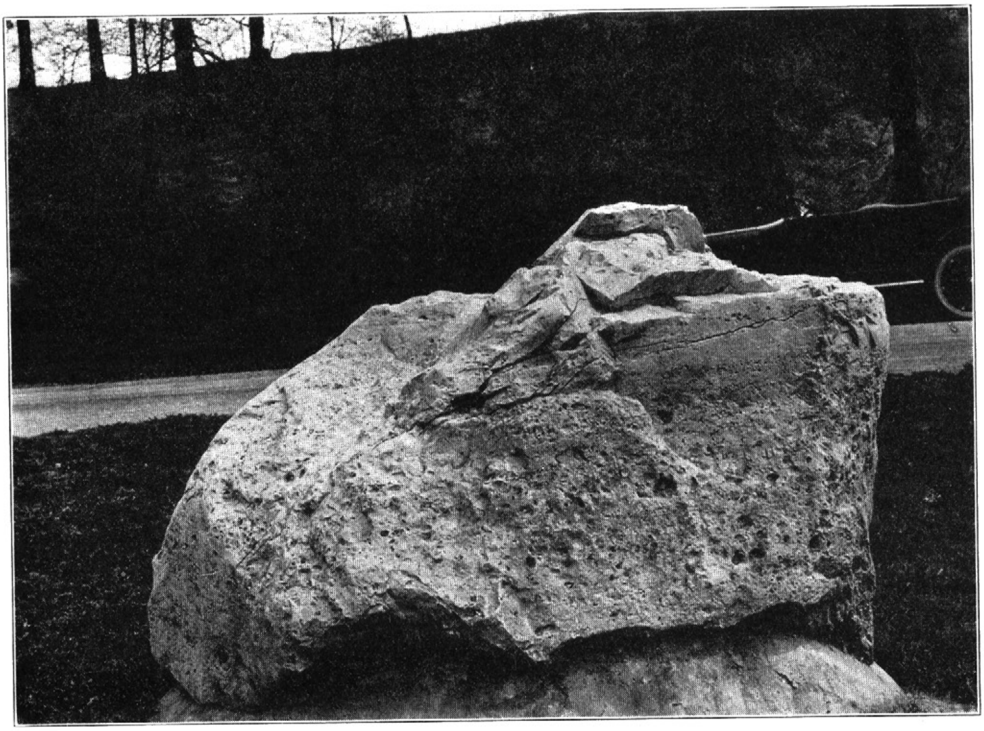


PLATE 1.—A LARGE LIMESTONE BOULDER THAT TRAVELED OVER 100 MILES WITH THE GLACIER

Champaign county was first covered by the Illinois glacier, which did its share toward leveling the region and covering it with a deposit of boulder clay. After this glaciation a long period elapsed, during which a soil now known as the Sangamon soil, was formed from this glacial deposit. Later a large part of the state, including all of Champaign county, was covered with a deposit of wind-blown material, called loess, which buried the old Sangamon soil that was formed from the Illinois glacial drift. The loess varied from a few feet to 100 feet in thickness, but in this county it was probably not over 10 feet thick. A new soil was formed from the loess, and this is called the Peorian soil. After a long period had again elapsed, another ice advance occurred—the early Wisconsin glacier. This covered the entire county, bringing with it immense quantities of material, which buried the loess and the Peorian soil.

The deepest total deposit of boulder clay in the county is at Champaign, where a boring showed 300 feet. The thinnest drift so far found is at Sidney, where it is 95 feet thick. The average depth over the county is 200 feet. This includes both Illinoisan and Wisconsin drift and loessial strata. Boulders are quite common in the drift and some are very large (see Plate 1). A few miles southeast of Philo, in Section 4, Township 17 North, Range 10 East, a very large mass of limestone occurs, 16 feet square, extending some distance below the surface. Other large masses are found in the same region. The Shelbyville moraine marks the outward limit of the early Wisconsin glacier. The Peorian soil which was buried by the last glacier, is found at depths varying from 60 to 100 feet. The Peorian soil itself varies from black soil to compressed peat or muck. No rock outcrop occurs in the county.

The Wisconsin glacier advanced and receded several times, each advance forming a distinct moraine. The Cerro Gordo moraine starts in this county near Mahomet and extends into Piatt county to the southwest, southeast of the Sangamon river. This is probably the oldest moraine in the county. The Champaign morainic system crosses the county in a general northwest-southeast direction. It enters the county north of Mahomet at the corner of McLean county. It divides at Champaign, one branch extending south and the other southeast, forming Yankee ridge. South of Sidney, the Yankee ridge divides, forming two ridges, one just south of Homer and the other north of Broadlands. Another very high ridge, a part of the Bloomington morainic system, crosses the northeast part of the county, extending northwest and southeast. Between these ridges are broad, flat to slightly undulating plains, much of which was swampy and has been artificially drained.

PHYSIOGRAPHY AND DRAINAGE

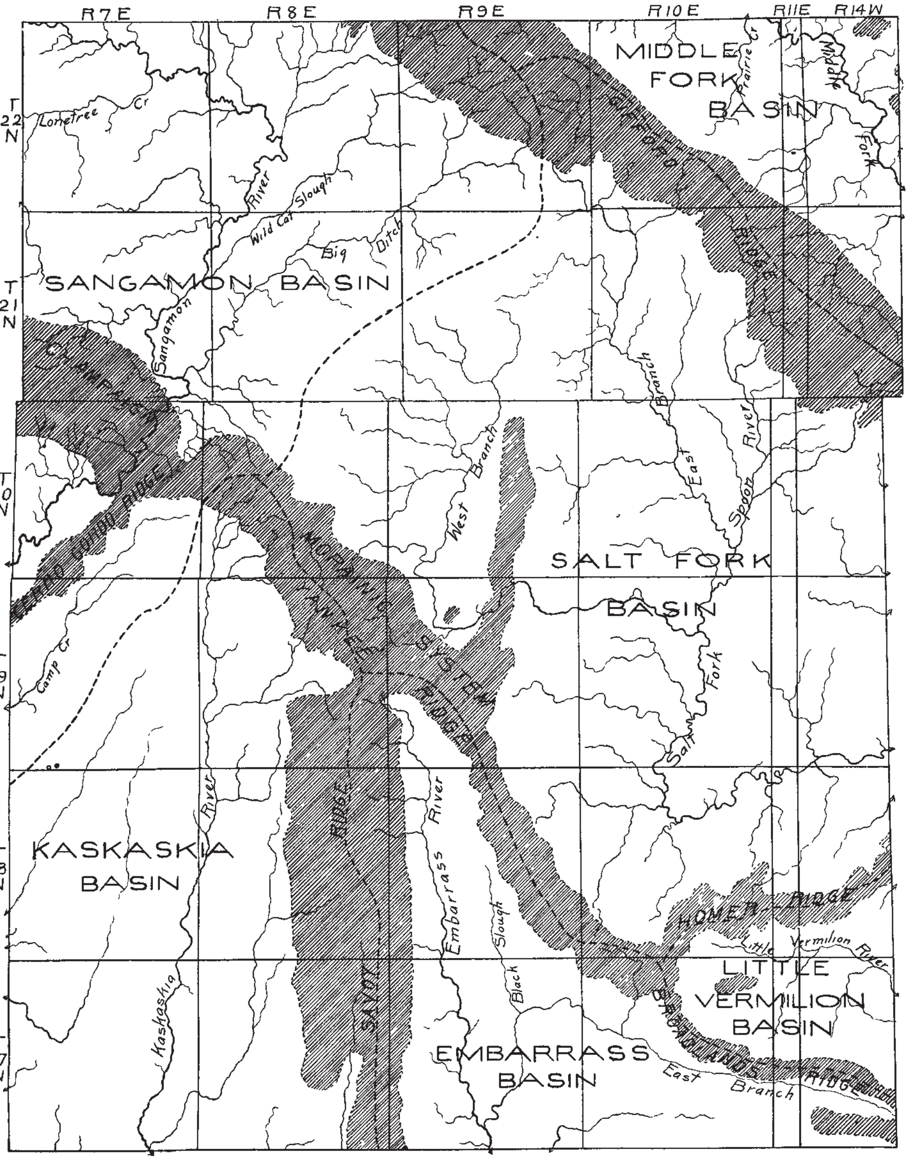
The altitude of Champaign county above sea level varies from 860 feet on the Champaign moraine north of Rising, to about 630 feet where the Salt Fork leaves the county northeast of Homer. The average altitude is about 710 feet. The altitudes of some other places in the county are as follows: Block, 715 feet; Bondville, 716; Bongard, 678; Broadlands, 680; Champaign, 740; Deers, 692; Dewey, 736; Dickerson, 757; Dillsburg, 750; Fisher, 732; Foosland, 734; Gifford, 810; Homer, 661; Howard, 741; Ivesdale, 683; Leverett, 736; Longview, 674; Ludlow, 773; Mahomet, 712; Mayview, 686; Ogden, 675; Penfield, 725; Pesotum, 720; Philo, 737; Rantoul, 758; Rising, 734; Sadorus, 692; Savoy, 740; Seymour, 697; St. Joseph, 673; Sidney, 672; Thomasboro, 736; Tipton, 673; Tolono, 736; Urbana, 721.

The county is divided into six drainage areas, as follows:

(1) The Sangamon basin (see Plate 2) includes the northwestern part of the intermorainal tract between the Champaign and Bloomington moraines. This basin is drained by the Sangamon river, which breaks thru the Champaign moraine near Mahomet. The Sangamon drains very little land south of the Champaign moraine because the Cerro Gordo ridge lies just east of the river valley and cuts off any streams from that direction.

(2) The Kaskaskia basin (the southwestern area) is drained by the Kaskaskia river and its tributaries. The east watershed is formed by the outer or west ridge of the Champaign moraine, the Savoy ridge, which extends south into Douglas county. In Champaign county this ridge forms the divide between the Embarrass and the Kaskaskia rivers, or between the Ohio and the Mississippi river systems.

(3) The Embarrass ("Ambraw") basin (the southeastern area) is drained by the Embarrass river and its branches, which include the Black Slough and East Branch. The latter rises in Vermilion county near Sidell and unites with the main stream about three-fourths of a mile north of the southern county line. To the north, the eastern side of the watershed is formed by the Yankee ridge, a part of the Champaign moraine. South of Sidney the ridge divides into the Homer and Broadlands ridges. The Broadlands branch forms the northern divide of the East Branch of the Embarrass.



MAP SHOWING THE MORAINES AND DRAINAGE BASINS OF CHAMPAIGN COUNTY, WITH APPROXIMATE MORAINIC BOUNDARIES. THE BROKEN LINES SHOW THE DIVIDES

(4) The Little Vermilion basin lies between the Homer and Broadlands ridges. This basin is drained by the Little Vermilion river, which flows eastward into Indiana, emptying into the Wabash river.

(5) The large Salt Fork basin lies between the Yankee ridge and the Gifford ridge, a part of the Bloomington morainic system, and extends from the east line of the county to a low ridge running southwest from Rantoul to the Champaign moraine east of Mahomet. This drainage area is comparatively flat, as is indicated by the large amount of black clay loam.

(6) The Middle Fork basin, lying in the northeast part of the county, is drained by Middle Fork of the Vermilion river. This stream is peculiar in that it has formed considerable areas of gravel terrace.

The glacial deposits with the variable beds of sand and gravel furnish the county an abundance of good water. Two small areas, one immediately northwest of St. Joseph and the other near Penfield, furnish flowing wells.

Soil Material and Soil Types

The early Wisconsin glacier left extensive deposits of boulder clay over the county, but the soils as a rule are not formed from this material. The fine material of the glacial drift was reworked by water and wind action, resulting in the deposition of several feet of fine material of loessial character, and from this the soils were formed. Originally this loessial deposit was very likely of more nearly uniform thickness, but subsequent erosion has removed a large part from the more rolling areas, where the loess now varies from 0 to 3 feet in thickness, and increased its depth in the lower-lying land which received the deposit, where now it may be from 6 to 8 feet deep.

The soils of the county are divided into four classes, as follows:

(a) Upland prairie soils, rich in organic matter. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat prairie land contains a higher amount of this constituent than the undulating or rolling prairie, because the grasses and roots grew more luxuriantly there, and the higher moisture content preserved them from complete decay.

The upland prairie soils include some areas of recent timber growth where certain kinds of trees have spread over the prairie, but this forestation has not been of sufficient duration to produce the characteristic timber soils. These areas of greater or less width are found along the border of most timber tracts, so that the timber actually extended a little farther than the soil type would indicate. A good illustration is found in Section 31, southeast of Philo. A grove locally known as Lynn Grove was started on the moraine, and altho the forest now covers 120 acres, yet it has not been there long enough to change the character of the soil. This indicates that several generations of trees would be necessary to change the soil type.

(b) Upland timber soils, including those zones along stream courses over which for a long period of time forests once extended. These soils contain much less organic matter than the prairie soils because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay. The timber lands are divided chiefly into two subclasses—the undulating and the hilly areas.

(c) Terrace soils, formed by deposits from flooded streams overloaded with coarse sediment, perhaps at the time of the melting of the glacier. Finer deposits which were later made upon the coarse, gravelly material now constitute the soil. Terrace soils were generally covered by forests.

(d) Swamp and bottom lands, which include the flood plains along streams and some small peaty swamp areas.

Table 1 gives the area of each type of soil in Champaign county and its percentage of the total area. It will be observed that 92.2 percent of the area consists of upland prairie soil, 4.89 percent of upland timber soil, .52 percent of terrace soil, and 2.39 percent of swamp and bottom-land soils. The accompanying maps show the location and boundary lines of every type of soil on every farm in the county, even down to areas of a few acres.

TABLE 1.—SOIL TYPES OF CHAMPAIGN COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (900, 1100), page 27			
926, 1126	Brown silt loam	720.00	460 800	72.86
920, 1120	Black clay loam	176.47	112 941	17.86
1121	Drab clay loam	9.58	6 131	.97
928, 1128	Brown-gray silt loam on tight clay	4.11	2 630	.42
1160	Brown sandy loam	.87	557	.09
		911.03	583 059	92.20
	(b) Upland Timber Soils (900, 1100), page 36			
934, 1134	Yellow-gray silt loam	45.16	28 902	4.57
935, 1135	Yellow silt loam	3.06	1 958	.31
1164	Yellow-gray sandy loam	.11	70	.01
		48.33	30 930	4.89
	(c) Terrace Soils (1500), page 44			
1527	Brown silt loam over sand or gravel	2.41	1 542	.24
1536	Yellow-gray silt loam over sand or gravel	2.71	1 734	.27
1560	Brown sandy loam	.07	45	.01
		5.19	3 322	.52
	(d) Swamp and Bottom-Land Soils (1400), page 45			
1454	Mixed loam	23.43	14 995	2.37
1401	Deep peat	.14	90	.02
1402	Medium peat on clay	.03	19	.003
		23.60	15 104	2.39
	Total	988.15	632 415	100.00

THE INVOICE AND INCREASE OF FERTILITY IN CHAMPAIGN COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average analysis of many soil samples, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient.[1] (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

The chemical analysis of a soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

In Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type in Champaign county—the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize it.

The soil to the depth indicated includes at least as much as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will

[1]For types of very limited extent, or of quite variable character (''mixed''), only one set of samples, or samples representing only the most common phase, may be collected for analysis, and such analyses have, of course, less application.

be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common upland soil of Champaign county, the brown silt loam prairie, does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for nine rotations (36 years).

With respect to phosphorus, the condition differs only in degree, this most important upland soil of the county containing no more of that element than would be required for fourteen crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium in this common soil type is sufficient for 28 centuries if only the grain is sold, or for more than 400 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2,400 and 550 years for magnesium, and about 10,500 and 250 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium; and, as explained in the

TABLE 2.—FERTILITY IN THE SOILS OF CHAMPAIGN COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils (900, 1100)								
926, 1126	Brown silt loam...	56 160	4 670	1 060	35 430	9 550	10 680		40
920, 1120	Black clay loam...	73 620	6 750	1 780	34 060	14 410	18 330	Often	Often
928, 1128	Brown-gray silt loam on tight clay	38 860	3 630	1 140	29 930	6 040	5 080		570
1121	Drab clay loam....	55 450	5 220	1 460	37 040	14 920	16 560	Often	Often
1160	Brown sandy loam.	29 540	2 520	840	26 840	4 060	6 560		120
	Upland Timber Soils (900, 1100)								
934, 1134	Yellow-gray silt loam............	25 200	2 350	930	35 070	6 650	7 430		30
935, 1135	Yellow silt loam...	17 360	1 200	860	35 320	5 500	6 480		20
1164	Yellow-gray sandy loam............	20 020	1 340	740	29 180	3 440	5 900		20
	Terrace Soils (1500)								
1536	Yellow-gray silt loam over sand or gravel..........	23 880	2 190	1 090	36 440	6 540	6 670		50
1527	Brown silt loam over sand or gravel	41 960	4 020	1 180	36 300	8 180	7 860		40
1560	Brown sandy loam.	69 660	6 220	1 500	31 100	6 720	11 220		20
	Swamp and Bottom-Land Soils (1400)								
1454	Mixed loam.......	61 840	5 530	1 660	41 570	17 720	23 400		Often
1401	Deep peat[1].......	258 990	24 510	1 370	7 950	6 310	72 180	102 180	
1402	Medium peat on clay[1]............	198 200	17 010	840	13 080	6 310	16 370		40

[1]Amounts reported are for 1 million pounds of deap peat and medium peat.

Appendix, with magnesium, and more especially with calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil of the most prevalent type in the county certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different types of soil in Champaign county with respect to their content of important plant-food elements is also very marked. The deep peat contains in the plowed soil of an acre twenty times as much nitrogen as the yellow silt loam, and about five times as much nitrogen but only one-fourth as much potassium as the brown silt loam. The total supply of phosphorus in the surface soil varies from 740 pounds per acre in the yellow-gray sandy loam to 1,780 pounds in the black clay loam. The magnesium and calcium vary from about 4,000 and 5,000 pounds in the lighter soils to about 20,000 pounds in some other types. One type contains an abundance of limestone, while some others are slightly acid in the surface, more strongly acid in the subsurface, and sometimes devoid of limestone even in the subsoil. More than 80 percent of the soils of the county contain no limestone in the surface or subsurface to a depth of 20 inches.

With an inexhaustible supply of nitrogen in the air and with 35,000 pounds of potassium in the most common prairie soil, the economic loss in farming such land with some acidity and with only 1,060 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that in less than one generation the average crop yields could be doubled by the proper use of limestone and phosphorus in rational farm systems, without change of seed or season and with very little more work than is now devoted to the fields. Fortunately, some definite field experiments have already been conducted on this most extensive type of soil on the University experiment fields in several counties, as at Urbana in Champaign county, at Sibley in Ford county, at Bloomington in McLean county, and for shorter periods in some other counties. Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been tried out on some of these experiment fields in different parts of central Illinois.

RESULTS OF FIELD EXPERIMENTS AT URBANA

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field (Series 100), oats on another (Series 200), and oats, cowpeas, and corn on the third field (Series 300) until 1901. From 1902 to 1910 the three-year rotation (with cowpeas in place of clover in 1902) was followed. The average yields are recorded in Table 3.

A small crop of cowpeas in 1902 and a partial crop of clover in 1904 constituted all the hay harvested during the first rotation, mammoth clover grown in

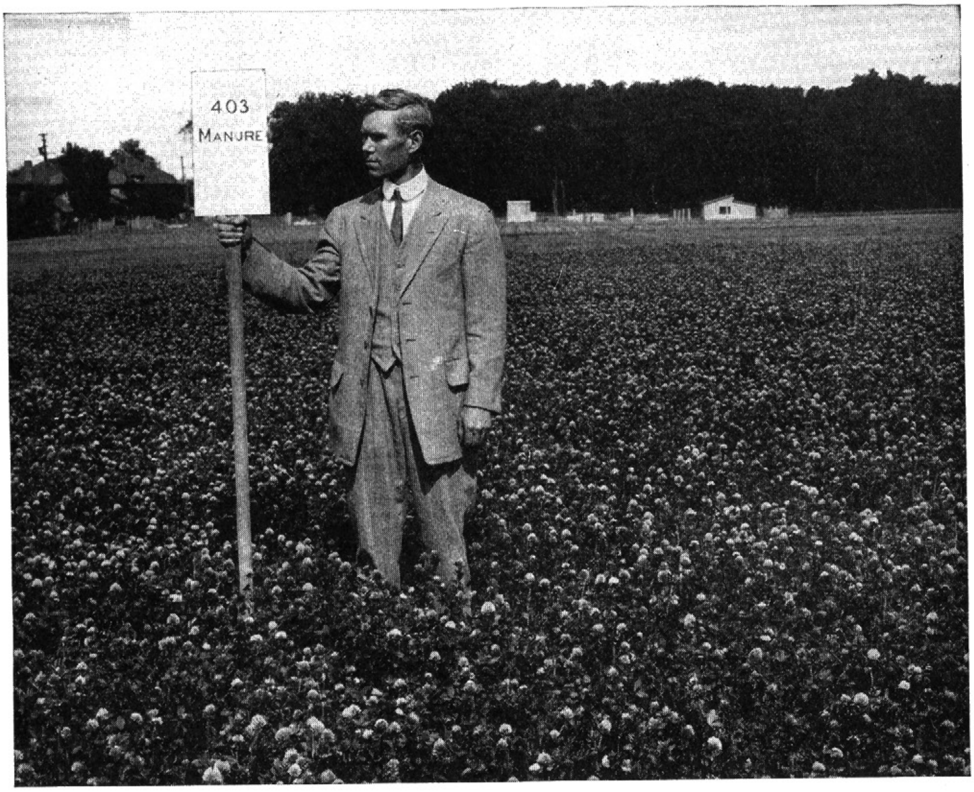


PLATE 2.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE APPLIED
YIELD, 1.43 TONS PER ACRE

1903 having lodged so that it was plowed under. The average yields of hay shown in the table represent one-third of the two small crops.

From 1902 to 1907 legume cover crops (Le), such as cowpeas and clover, were seeded in the corn at the last cultivation on Plots 2, 4, 6, and 8, but the growth was small and the net effect, if any, was to decrease the returns from the regular crops. Since 1907 crop residues (R) have been returned to those plots. These consist of the stalks of corn, the straw of small grains, and all legumes except alfalfa hay and the seed of clover and soybeans, including since 1911 (except when alfalfa follows wheat) a legume cover crop (usually sweet clover) seeded on the young wheat and plowed under the next spring for corn.

On Plots 3, 5, 7, and 9, manure (M) was applied for corn at the rate of 6 tons per acre during the second rotation, and subsequently for each rotation as many tons of manure are applied for corn as there have been tons of air-dry produce harvested from the corresponding plots.

Lime (L) was applied on Plots 4 to 10 at the rate per acre of 250 pounds of air-slaked lime in 1902 and 600 pounds of limestone in 1903. Subsequently 2 tons per acre of limestone were applied to these plots on Series 100 in 1911, on Series 200 in 1912, on Series 300 in 1913, and on Series 400 in 1914; also 2½ tons per acre on Series 500 in 1911, two more fields having been brought into rotation, as explained on the following page.

PLATE 3.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE, LIMESTONE, AND PHOSPHORUS APPLIED
YIELD, 2.90 TONS PER ACRE

Phosphorus (P) has been applied on Plots 6 to 9 since 1902 at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal; but beginning with 1908, one-half of each phosphorus plot has received 600 pounds of rock phosphate in place of the 200 pounds of bone meal, the usual practice being to apply and plow under at one time all phosphorus and potassium required for the rotation.

Potassium (K=kalium) has been applied on Plots 8 and 9 at the yearly rate of 42 pounds per acre in 100 pounds of potassium sulfate, regularly in connection with the bone meal and rock phosphate.

On Plot 10 about five times as much manure and phosphorus are applied as on the other plots, but this "extra heavy" treatment was not begun until 1906, only the usual lime, phosphorus, and potassium having been applied in previous years. These heavy applications are made in an attempt to determine the climatic possibilities in crop yields by removing the limitations of inadequate fertility.

Series 400 and 500 were cropped in corn and oats from 1902 to 1910, but the various plots were treated the same as the corresponding plots in the three-year rotation. Beginning with 1911, the five series have been used for a combination rotation; wheat, corn, oats, and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then brought under the four-crop

TABLE 3.—YIELDS ?ER ACRE, THREE-YEAR AVERAGES: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	First rotation, 1902-1904						Second rotation, 1905-1907						Third rotation, 1908-1910					
	Soil treat- ment	Corn, bu.	Oats, bu.	Hay, tons	Value of 3 crops		Soil treat- ment	Corn, bu.	Oats, bu.	Clover,[1] tons	Vaue of 3 crops		Soil treat- ment	Corn, bu.	Oats, bu.	Clover, tons (bu.)	Value of 3 crops	
					Lower prices	Higher prices					Lower prices	Higher prices					Lower prices	Higher prices
1	0........	75.4	48.8	.49	$62.12	$86.96	0........	71.5	46.6	1.64	$70.79	$99.10	0........	49.4	40.8	2.30	$64.02	$89.62
2	Le.......	77.4	45.1	.44	61.14	85.60	Le.......	68.5	52.0	1.60	71.05	99.46	R.......	51.5	43.4	(1.93)	62.41	87.38
3	0........	75.3	50.4	.41	61.91	86.66	M.......	80.5	54.8	1.89	81.07	113.50	M.......	69.3	46.2	2.53	78.43	109.80
4	LeL.....	78.4	47.3	.42	62.32	87.24	LeL.....	72.3	58.6	1.79	74.49	108.48	RL......	58.1	45 7	(2.02)	67.53	94.54
5	L........	80.8	58.2	.44	68.08	95.32	ML......	84.8	59.8	2.11	87.42	122.36	ML......	74.9	47.5	2.94	85.85	120.18
6	LeLP....	88.0	52.5	.50	70.00	98.00	LeLP....	90.4	70.7	2.93	102.78	143.90	RLP.....	83.8	54.5	(2.64)	90.10	126.14
7	LP.......	88.8	56.6	.98	76.84	107.58	MLP....	93.2	71.6	2.94	104.64	146.50	MLP....	86.6	55.4	4.17	107.16	150.02
8	LeLPK...	90.1	48.3	.64	70.77	99.06	LeLPK...	93.8	71.7	3.17	107.28	150.20	RLPK...	86.7	53.5	(1.99)	84.65	118.52
9	LPK.....	90.5	54.3	1.34	80.37	112.52	MLPK...	95.6	66.9	3.26	107.16	150.02	MLPK...	90.9	53.6	3.90	105.89	148.24
10	LPK.....	86.5	53.2	1.23	76.83	107.56	MxLPx...	90.1	62.9	3.31	103.31	144.64	MxLPx...	81.3	54.3	3.79	100.27	140.38

Le=legume cover crop; L=lime; P=phosphorus; K=potassium; M=manure; x=extra heavy applications of manure and phosphorus; R=crop residues (corn stalks, straw of wheat and oats, and all legumes except seed).

[1]These clover yields were printed incorrectly in some previous reports.

TABLE 4.—YIELDS PER ACRE, SEVEN-YEAR AVERAGES, 1911-17; URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	Soil treatment	Wheat bu.	Corn bu.	Oats bu.	Soybeans –4, tons (bu.)	Clover –3, tons (bu.)	Alfalfa ton	Value of 5 crops	
								Lower prices	Higher prices
1	0...........	21.9	54.0	53.0	1.60	1.60	2.12	$111.63	$156.28
2	R..........	26.3	56.1	54.5	(21.3)	(.87)	2.15	113.55	158.98
3	M..........	24.6	63.9	63.5	1.68	2.20	2.10	121.98	170.78
4	RL.........	28.3	60.2	55.8	(20.7)	(1.26)	2.33	121.25	169.76
5	ML.........	30.6	64.1	65.8	1.72	2.73	2.76	138.11	193.34
6	RLP........	42.6	67.0	72.6	(22.6)	(2.05)	3.57	162.44	227.42
7	MLP........	40.1	68.2	71.7	1.92	3.50	3.58	164.65	230.52
8	RLPK......	41.7	66.1	73.5	(24.2)	(1.38)	3.59	159.79	223.70
9	MLPK......	39.4	64.5	75.1	2.09	3.36	3.64	164.43	230.22
10	MxLPx......	42.7	62.7	76.6	2.17	3.42	3.70	168.76	236.26

system to make place for alfalfa on one of the other fields for another five-year period, and so on. (See Table 4.)

From 1911 to 1917 soybeans were substituted four years because of clover failure; accordingly four-sevenths of the soybeans and three-sevenths of the clover are used to compute values. Alfalfa from the 1911 seeding so nearly failed that after cutting one crop in 1912 the field was plowed and reseeded. The average yield reported for alfalfa in Table 4 is one-seventh of the combined crops of 1912, 1913, 1914, 1915, 1916, and 1917.

The "lower prices" allowed for produce are $1 a bushel for wheat and soybeans, 50 cents for corn, 40 cents for oats, $10 for clover seed, and $10 a ton for hay; while the "higher prices" are 40 percent more than these values, or $1.40 for wheat and soybeans, 70 cents for corn, 56 cents for oats, $14 for clover seed, and $14 a ton for hay. The two sets of values are used to emphasize the fact that a given practice may or may not be profitable, depending upon the prices of farm produce. The lower prices are conservative, and unless otherwise stated, they are the values regularly used in the discussion of results. It should be understood that the increase produced by manures and fertilizers requires increased expense for binding twine, shocking, stacking, baling, threshing, hauling, storing, and marketing. Measured by Illinois prices for the past ten years, these lower values are high enough for crops standing in the field ready for harvest.

The cost of limestone delivered at a farmer's railroad station in carload lots averages about $1.25 per ton. Steamed bone meal in carloads costs from $30 to $40 per ton. Fine-ground raw rock phosphate containing from 260 to 280 pounds of phosphorus, or as much as the bone meal contains ton for ton, but in less readily available form, usually costs the farmer from $8 to $10 per ton in carloads. (Acid phosphate carrying half as much phosphorus, but in soluble form, may cost three times as much as the raw rock, or from $24 to $30 per ton delivered in carload lots in central Illinois.) Under normal conditions potassium costs about 6 cents a pound, or $2.50 per acre per annum for the amount applied in these experiments, the same as the cost of 500 pounds of rock phosphate at $10 per ton.

To these cash investments must be added the expense of hauling and spreading the materials. This will vary with the distance from the farm to the railroad station, with the character of the roads, and with the farm force and the immedi-

PLATE 4.—CLOVER ON URBANA FIELD, SOUTH FARM
CROP RESIDUES PLOWED UNDER

ate requirements of other lines of farm work. It is the part of wisdom to order such materials in advance to be shipped when specified, so that they may be received and applied when other farm work is not too pressing and, if possible, when the roads are likely to be in good condition.

The practice of seeding legume cover crops in the cornfield at the last cultivation where oats are to follow the next year has not been found profitable, as a rule, on good corn-belt soil; but the returning of the crop residues and cover crops to the land may maintain the nitrogen and organic matter equally as well as the hauling and spreading of farm manure—and this makes possible permanent systems of farming on grain farms as well as on live-stock farms, provided, of course, that other essentials are supplied. (Clover with oats or wheat, as a cover crop to be plowed under for corn, often gives good results. Sweet clover is most promising for this purpose.)

At the lower prices for produce, manure (6 tons per acre) was worth $1.71 a ton as an average for the first three years during which it was applied (1905 to 1907). For the next rotation the average application of 10.21 tons per acre on Plot 3 was worth $14.41, or $1.41 a ton. During the next four years, 1911 to 1914, the average amount applied (once for the rotation) on Plot 3 was 11,35 tons per acre, worth $9.17, or 81 cents a ton, as measured by its effect on the

PLATE 5.—CLOVER ON URBANA FIELD, SOUTH FARM
FINE-GROUND ROCK PHOSPHATE PLOWED UNDER WITH CROP RESIDUES

wheat, corn, oats, soybeans, and clover. Thus, as an average of the ten years' results, the farm manure applied to Plot 3 has been worth $1.20 a ton on common corn-belt prairie soil, with a good crop rotation including legumes. During the last four years of this ten-year period moisture was the limiting factor to such an extent as probably to lessen the effect of the manure.

Aside from the crop residues and manure, each addition affords a duplicate test as to its effect. Thus the effect of limestone is ascertained by comparing Plots 4 and 5, not with Plot 1, but with Plots 2 and 3; and the effect of phosphorus is ascertained by comparing Plots 6 and 7 with Plots 4 and 5, respectively.

As a general average, the plots receiving limestone have produced $1.97 an acre a year more than those without limestone, and this corresponds to more than $6 a ton for all the limestone applied; but the amounts used before 1911 were so small and the results vary so greatly with the different plots, crops, and seasons that final conclusions cannot be drawn until further data are secured, the first 2-ton applications having been completed only for 1914. However, all comparisons by rotation periods show some increase for limestone, these increases varying from $1.18 on three acres (Plot 4) during the first rotation, to $16.13 on five acres (Plot 5) as an average of the last seven years. The need of limestone for the best results and highest profits seems well established.

As an average of duplicate trials (Plots 6 and 7), phosphorus in 200 pounds of bone meal produced increases valued at $2.74 per acre per annum for the first three years and at $7.59 for the next three; and the corresponding subsequent average increases from bone meal and raw phosphate (one-half plot of each) were $7.31 for the third rotation and $6.77 for the last seven years, 1911 to 1917. In the residue system, the average yearly acre-increase for phosphorus was $6 for the first six years, and $8.02 for the next ten years; and in the manure system the corresponding average increases were $4.33 for the first six years and $5.85 for the next ten years. The annual expense per acre for phosphorus is $3.50 in bone meal at $35 a ton, or $2.70 for rock phosphate at $9 a ton.

Potassium applied at an estimated normal cost of $2.50 an acre a year, seemed to produce slight but very unprofitable increases, as an average, during the first and second rotations; but subsequently those increases have been almost entirely lost in reduced average yields, the net result to date being an average loss of $2.48 per acre per annum, or a loss of 99 cents for every dollar invested in potassium.

Thus phosphorus nearly paid its cost during the first rotation, and has subsequently paid its annual cost and about 100 percent net profit; while potassium, as an average, has produced no effect, and money spent for its application has been lost. These field results are in harmony with what might well be expected on land naturally containing in the plowed soil of an acre only about 1,100 pounds of phosphorus and 35,000 pounds of potassium.

The total value of five average crops harvested from the untreated land during the last seven years is about $111. Where limestone and phosphorus have been used together with organic manures (either crop residues or farm manure), the corresponding value is $163. Thus 200 acres of the properly treated land would produce almost as much in crops and in value as 300 acres of the untreated land.

The excessive applications on Plot 10 have usually produced rank growth of straw and stalk, with the result that oats have often lodged badly and corn has frequently suffered from drouth and eared poorly. On the whole, the extra treatment has produced but little increase over Plots 6 to 9. The largest yield of corn on Plot 10 was 118 bushels per acre in 1907.

The field investigations above described have been conducted on fifty experimental plots, laid out by Eugene Davenport a few months after he entered the service of Illinois in 1895.

But it so happens that the oldest soil experiment field in the United States is located at the University of Illinois. It was once on the farm, but is now on the campus of the institution, owing to the development and expansion of the University. This oldest field was started by George E. Morrow, for many years Professor of Agriculture. Here, on part of the field, corn has grown on the same land every year since 1879; on another part, corn and oats have grown in alternation; and on a third part, corn, oats, and clover have grown in rotation. These are known as the Morrow Plots.

On these plots, with no restoration of fertility, the acre-value of the produce, as an average of the ten-year period 1908 to 1917, was $14.15 where corn is grown every year, $17.10 where corn and oats are alternated, and $18.19 where corn, oats, and clover are rotated.

TABLE 5.—YIELDS PER ACRE ON MORROW (M) AND DAVENPORT (D) PLOTS, URBANA

Serial plot No.	Soil treatment	10-year average, 1908–17			Wheat, bu. 7-yr. av.	Alfalfa, tons 5-yr. av.	Average acre-value[5]
		Corn, bu.	Oats, bu.	Clover, T (bu.)[1]			
M 3	None	28.3	....	....	....	....	$14.15
M 4	None	37.6[2]	38.5[2]	....	....	....	17.10
M 5	None	40.1[3]	41.8[4]	1.78[3]	....	....	18.19
D 1	None	52.6	49.3	1.97	21.9	....	21.90
D 1	None	52.6	49.3	1.97	21.9	3.18	23.88
D 2	Residues	54.7	51.2	(1.09)	26.3	2.99	24.19
D 3	Manure	65.5	58.3	2.09	24.6	2.93	26.17
D 4	Residues, lime	59.6	52.8	(1.82)	28.3	3.25	25.98
D 5	Manure, lime	67.3	60.3	2.39	30.6	3.80	30.05
D 6	Residues, lime, phosphorus	72.0	67.2	(2.29)	42.6	4.81	35.30
D 7	Manure, lime, phosphorus	73.7	66.8	3.07	40.1	4.82	36.51
D 8	Residues, lime, phosphorus, potassium	72.2	67.5	(1.88)	41.7	4.83	34.38
D 9	Manure, lime, phosphorus, potassium	72.4	68.7	3.01	39.4	4.86	36.36

[1]Or equivalent in cowpeas or soybeans.
[2]Five-year average. [3]Three-year average. [4]Four-year average.
[5]Prices: 50 cents a bushel for corn, 40 cents for oats, $1 for wheat and soybeans, $10 for clover seed, $10 a ton for hay.

On the Davenport Plots, if we include the alfalfa yields for five years, and the wheat yields for seven years, with the ten-year averages for the corn, oats, and clover, the acre-value becomes $23.88 with no soil treatment, $35.30 with residues, limestone, and phosphorus, and $36.51 with manure, limestone, and phosphorus.

More complete details regarding these averages are given in Table 5.

As an average of the results secured during the twelve years 1903 to 1914, on the University South Farm where fine-ground raw rock phosphate is applied at the rate of 500 pounds per acre per annum on the typical brown silt loam prairie soil, the return for each ton of phosphate[1] used has been $19.39 on Series 100 and $17.24 on Series 200, with the lower prices allowed for produce, the rotation being wheat, corn, oats, and clover (or soybeans). This gives an average return of $18.31 for each ton of phosphate applied. Averages for each rotation period show the following values for the increase per ton of phosphate used:

	Lower prices	Higher prices
First rotation, 1903 to 1906	$11.80	$16.52
Second rotation, 1907 to 1910	16.19	22.66
Third rotation, 1911 to 1914	26.98	37.77

Thus, at the lower prices for produce, the rock phosphate paid back more than its cost during the first rotation, more than 1½ times its cost during the second rotation, and nearly three times its cost during the third rotation period.

One ton of fine-ground rock phosphate costs about the same as 500 pounds of steamed bone meal. Altho in less readily available form, the rock phosphate contains as much phosphorus, ton for ton, as the bone meal; and, when equal money values are applied in connection with liberal amounts of decaying organic matter, the natural rock may soon give as good results as the bone—and, by

[1]During the first four years Series 100 received only 1,500 pounds per acre of phosphate, and both series received also ½ ton per acre of limestone, the effect of which probably would be slight, as may be judged from the data secured later and reported herein.

TABLE 6.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 100
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1903	Corn 1904	Oats 1905	Wheat 1906	Clover 1907	Corn 1908	Oats 1909	Clover 1910	Wheat[2] 1911	Corn 1912	Oats 1913	Soybeans 1914	Value 1st four years	Value 2d four years	Value 3d four years		Wheat 1915	Corn 1916	Oats 1917
		Bushels or tons per acre[1]												Lower prices	Lower prices	Lower prices	Higher prices	Bushels per acre	Bushels per acre	Bushels per acre
163	RP....	45.1	54.1	57.5	39.8	(.83)	72.0	45.4	(.60)	46.9	74.9	26.8	(16.6)	$112.40	$ 68.46	$111.67	$156.34	46.9	37.6	78.8
166	RP....	43.8	49.3	60.9	36.5	(1.00)	74.9	40.8	(1.30)	53.4	79.5	24.6	(17.5)	107.41	76.77	120.49	168.68	44.4	41.6	74.1
169	R.....	42.7	39.5	49.3	28.4	(.90)	65.0	39.9	(1.70)	36.7	67.9	19.1	(15.3)	89.22	74.46	93.59	131.02	26.6	29.2	59.9
170	M.....	41.8	38.7	52.2	26.2	2.56	69.6	40.1	2.87	35.9	76.7	22.5	1.09	87.33	105.14	94.15	131.80	31.8	37.2	67.4
173	MP....	35.4	53.3	54.6	32.8	3.65	78.4	39.8	4.23	52.7	83.7	29.6	1.45	98.99	133.92	120.89	169.24	50.5	41.9	78.4
176	MP....	39.3	58.1	61.9	38.8	3.74	79.5	40.0	4.23	51.0	85.6	32.1	1.52	112.26	135.45	121.84	170.58	48.9	41.5	75.1
163	RLP...	....	....	....	....	....	....	....	....	49.9	87.0	28.2	(18.1)	....	....	122.78	171.88	50.9	47.2	57.3
166	RLP...	....	....	....	....	....	....	....	....	53.6	81.4	26.8	(18.0)	....	....	123.02	172.22	49.6	45.7	66.6
169	R.....	....	....	....	....	....	....	....	....	33.8	62.7	17.0	(15.2)	....	....	87.15	122.00	25.9	33.6	61 4
170	M.....	....	....	....	....	....	....	....	....	32.4	74.4	22.0	1.09	....	....	89.30	125.02	31.2	34.5	63.1
173	MLP...	....	....	....	....	....	....	....	....	51.3	85.7	28.0	1.37	....	....	119.05	166.66	52.4	46.6	63.6
176	MLP...	....	....	....	....	....	....	....	....	51.0	85.6	30.9	1.47	....	....	120.86	169.20	53.0	44.3	66.1

TABLE 7.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 200
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Oats 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Oats 1908	Wheat 1909	Wheat[2] 1910	Corn 1911	Oats 1912	Soybeans 1913	Wheat 1914	Value 1st four years	Value 2d four years	Value 3d four years		Corn 1915	Oats 1916	Soybeans 1917 Hay
		Bushels or tons per acre[1]												Lower prices	Lower prices	Lower prices	Higher prices	Bushels per acre	Bushels per acre	Tons per acre
263	RP....	24.7	25.7	32.1	.82	65.3	31.3	42.5	43.7	52.3	72.9	(13.7)	30.6	$60.46	$131.37	$ 99.61	$139.46	57.9	57.0	1.93
266	RP....	23.1	24.5	29.3	.80	59.7	26.7	40.7	32.3	50.2	75.7	(12.3)	33.9	56.34	113.53	101.58	142.22	56.4	58.5	1.90
269	R.....	26.8	22.5	26.8	.86	57.9	31.5	39.4	25.3	35.5	61.9	(10.7)	16.1	55.12	106.25	69.31	97.02	45.9	51.6	1.68
270	M.....	22.0	21.5	24.0	.82	55.3	30.0	37.1	28.7	43.1	67.8	.84	17.4	49.60	105.45	74.47	104.24	57.0	58.9	1.73
273	MP....	23.9	25.0	27.8	.77	62.5	29.5	43.4	43.7	38.6	69.4	1.17	37.2	55.06	130.15	95.96	134.34	61.5	76.9	1.74
276	MP....	16.1	25.3	30.7	.68	58.0	27.9	44.1	38.2	48.0	68.6	1.34	42.0	54.06	122.46	106.84	149.58	57.6	74.8	1.85
263	RLP...	....	....	....	....	....	....	....	49.0	50.3	78.9	(13.2)	40.4	....	....	110.31	154.44	50.0	65.5	2.01
266	RLP...	....	....	....	....	....	....	....	45.2	47.1	78.7	(10.3)	36.0	....	....	101.33	141.86	55.8	64.0	2.08
269	R.....	....	....	....	....	....	....	....	35.3	45.3	68.4	(10.5)	20.7	....	....	81.21	113.70	53.3	60.0	2.28
270	M.....	....	....	....	....	....	....	....	33.3	45.2	73.2	1.12	20.1	....	....	83.18	116.46	55.5	66.8	1.81
273	MLP...	....	....	....	....	....	....	....	46.2	53.7	69.0	1.27	46.2	....	....	113.35	158.58	49.6	78.4	1.90
279	MLP...	....	....	....	....	....	....	....	39.5	50.6	69.5	1.24	49.0	....	....	114.50	160.30	53.5	75.9	1.96

[1]For legumes, figures in parentheses indicate bushels of seed; the others, tons of hay.
[2]From 1911 in Series 100, and from 1910 in Series 200, the acre-yields are based on half-plots, limestone having been applied to one half of each of the plots indicated.

supplying about four times as much phosphorus, the rock provides for greater durability.

The results just given represent averages covering the residue system and the live-stock system, both of which are represented in this crop rotation on the South Farm.

Ground limestone at the rate of 8 tons per acre was applied to the east half of these series of plots (excepting the check plots, which receive only residues or manure), beginning in 1910 on Series 200 and in 1911 on Series 100. Subsequent applications are made of 2 tons per acre each four years, beginning in 1914 on Series 200 and in 1915 on Series 100. As an average of the results from both series, the crop values were increased during the third rotation, 1911-1914, as follows:

	Residue System		Live-Stock System	
	Lower prices	Higher prices	Lower prices	Higher prices
Gain for phosphate	$26.89	$37.64	$27.07	$37.90
Gain for limestone	3.29	4.60	3.63	5.08

Detailed records of these investigations are given in Tables 6 and 7, the data being reported by half-plots after 1910-1911. (Series 300 and 400, which are also used in this rotation, are located in part upon black clay loam and a heavy phase of brown silt loam.)

Results of Experiments on Sibley Field

Table 8 gives the results obtained during twelve years from the Sibley soil experiment field located in Ford county on the typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when the addition of phosphorus produced an increase of 8 bushels, nitrogen produced no increase, but nitrogen *and* phosphorus increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appeared to become the most limiting element, the increase in the corn in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus; while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land apparently grew less productive, whereas, on land receiving both phosphorus and nitrogen, the yield appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910 the yield of the highest producing plot exceeded the yield of the same plot in 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of

1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment was seen. Phosphorus appeared to be the first limiting element again in 1909, 1910, and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results. In 1913 wheat averaged 6.6 bushels without nitrogen or phosphorus (Plots 101, 102, 105) and 22.4 bushels where both nitrogen and phosphorus were added (Plots 106, 109, 110).

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
		Bushels per acre											
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4	5.5
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6	6.8
103	Lime, nitro	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3	18.3
104	Lime, phos	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3	10.7
105	Lime, potas	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1	7.5
106	Lime, nitro., phos	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2	24.7
107	Lime, nitro., potas	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6	19.2
108	Lime, phos., potas	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7	11.8
109	Lime, nitro., phos., potas	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2	24.5
110	Nitro., phos., potas	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1	18.0

Increase: Bushels per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
For nitrogen	.0	.3	2.8	1.1	2.5	9.2	11.6	-9.8	-5.0	.2	-60.3	11.5
For phosphorus	1.3	8.3	17.8	4.6	5.6	4.6	.9	3.4	18.0	9.4	6.7	3.9
For potassium	-4.0	-4.1	-.3	-1.5	-1.7	-4.0	-2.5	-5.6	.2	-.6	-2.5	.7
For nitro., phos. over phos	-4.0	6.8	-4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	-50.1	14.0
For phos., nitro., over nitro	-2.7	14.8	10.9	12.4	24.8	24.2	9.3	14.3	26.6	12.9	16.9	6.4
For potas., nitro., phos. over nitro., phos	1.4	-3.2	-5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0	-.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops: Lower prices	Total value of twelve crops: Higher prices
101	None	$246.98	$345.78
102	Lime	266.45	373.02
103	Lime, nitrogen	253.49	354.88
104	Lime, phosphorus	311.11	435.56
105	Lime, potassium	239.03	334.64
106	Lime, nitrogen, phosphorus	352.73	493.82
107	Lime, nitrogen, potassium	283.08	396.32
108	Lime, phosphorus, potassium	292.71	409.80
109	Lime, nitrogen, phosphorus, potassium	368.45	515.82
110	Nitrogen, phosphorus, potassium	346.38	484.94

Value of Increase per Acre in Twelve years

	Lower prices	Higher prices
For nitrogen	-$12.96	-$18.14
For phosphorus	44.66	62.54
For *nitrogen* and phosphorus over phosphorus	41.62	58.26
For *phosphorus* and nitrogen over nitrogen	99.24	138.94
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	15.72	22.00

In the lower part of Table 8 is shown the total value of the twelve crops from each of the ten different plots, the amounts varying at the lower prices (50 cents a bushel for corn, 40 cents for oats, and $1 for wheat) from $239.03 to $368.45 per acre. Phosphorus without nitrogen has produced $44.66 in addition to the increase by lime, but with nitrogen it has produced $99.24 above the crop values where only lime and nitrogen have been used. The results show that in 26 cases out of 48 the addition of potassium has decreased the crop yields. Even when applied in addition to phosphorus, and with no effort to liberate potassium from the soil by adding organic matter, potassium has produced no increase in crop values as an average of the results from Plots 108 and 109.

By comparing Plots 101 and 102, and also 109 and 110, it is seen that lime has produced an average increase of $20.77, or $1.73 an acre a year. The increase on these plots is nearly the same as on the field at Urbana, and it suggests that the time is here when limestone must be applied to some of these brown silt loam soils.

While nitrogen, on the whole, has produced an appreciable increase, especially on those plots to which phosphorus has also been added, it has cost, in commercial form, so much above the value of the increase produced that the only conclusion to be drawn, if we are to utilize the fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Tables 9 and 10, giving all results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

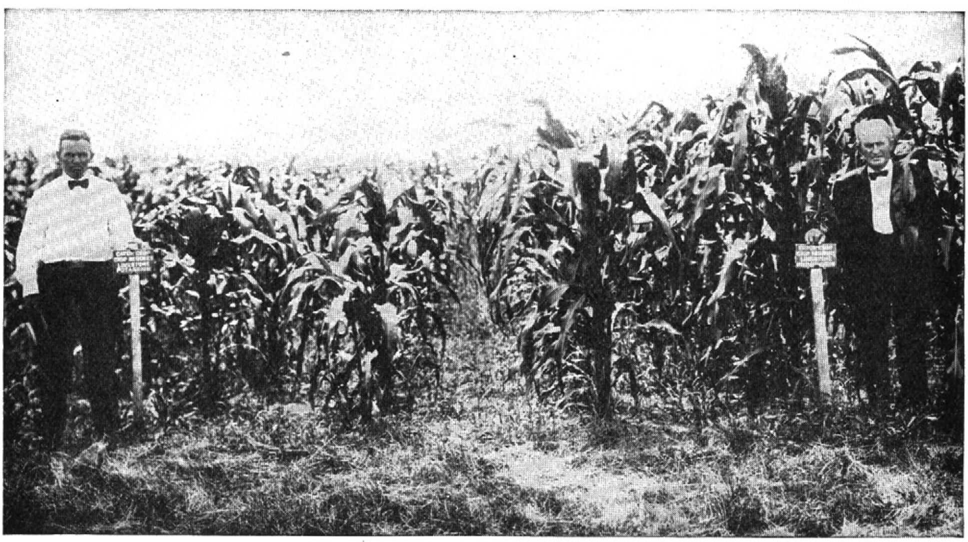


PLATE 6.—CORN IN 1912 ON BLOOMINGTON FIELD
ON LEFT, RESIDUES, LIME, AND POTASSIUM: YIELD, 58.9 BUSHELS
ON RIGHT, RESIDUES, LIME, AND PHOSPHORUS: YIELD, 86.1 BUSHELS

Table 9.—Crop Yields in Soil Experiments, Bloomington Field
Brown Silt Loam Prairie; Early Wisconsin Glaciation

Plot	Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910	Wheat 1911	Corn 1912	Corn 1913	Oats 1914	Soy-beans[4] 1915	Wheat 1916	Corn 1917
		Bushels or tons per acre[2]															
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5	55.2	32.4	29.8		20.5	24.3
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.5	47.9	30.0	40.6		15.8	19.2
103	Lime, crop residues	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5	37.5	30.8		21.1	29.6
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5	44.1	45.0		38.8	44.0
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8	32.1	35.8		16.7	30.2
106	Lime, residues, phosphorus	43.9	77.6	85.3	50.9	([3])	78.9	45.8	72.5	(1.67)	60.2	86.1	50.4	62.3		40.2	47.6
107	Lime, residues, potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9	34.5	34.5		18.7	31.1
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	79.2	49.4	63.1		39.9	47.6
109	Lime, residues, phosphorus, potas.	52.7	80.9	90.5	51.9	([3])	88.4	58.1	64.2	(.42)	60.4	83.4	49.0	54.4		43.8	48.3
110	Residues, phosphorus, potassium	52.3	73.1	71.4	51.1	([3])	78.0	51.4	55.3	(.60)	61.0	78.3	33.8	44.8		39.2	51.2
	Increase: Bushels or Tons per Acre																
	For residues	-1.9	-.8	9.0	1.7	-.12	1.2	1.6	-4.2		3.1	14.6	7.5	-9.8		5.3	10.4
	For phosphorus	4.7	12.7	11.9	10.4	1.07	19.0	12.2	10.2	3.12	35.1	26.6	14.1	4.4		23.0	24.8
	For potassium	.7	-3.9	1.7	4.4	-.07	1.0	.9	-8.3	.15	-.8	9.9	2.1	-4.8		.9	11.0
	For residues, phosphorus over phos.	2.2	4.6	12.6	11.7	-1.65	-3.2	-1.7	8.7		2.6	11.6	6.3	17.3		1.4	3.6
	For phosphorus, residues over residues	8.8	18.1	15.5	20.4	-.46	14.6	8.9	23.1	(.84)	34.6	23.6	12.9	31.5		19.1	18.0
	For potas., res., phos., over res., phos.	8.8	3.3	5.2	1.0	.00	9.5	12.3	-8.3	(-1.25)	.2	-2.7	-1.4	-7.9		3.6	.7

[1]Commercial nitrogen was used from 1902 to 1905, after which crop residues were substituted.
[2]For clover the figures indicate tons per acre, except where in parentheses, in which case they indicate bushels of seed.
[3]Clover smothered by previous wheat crop.
[4]The soybeans in 1915 were entirely destroyed by hail. Nothing was harvested and the residue was plowed under on all plots.

The general results of the first twelve years' work tell much the same story as those from the Sibley field. The rotations differed after 1905 by the use of clover and the discontinuing of the use of commercial nitrogen,—in consequence of which phosphorus without commercial nitrogen, on the Bloomington field, produced an even larger increase ($140.89) than was produced by phosphorus and nitrogen over nitrogen on the Sibley field ($99.24).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101 occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 9 are considered reliable. They not only furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

Wherever nitrogen has been provided, either by direct application or by the use of legume crops, the addition of the element phosphorus has produced very marked increases, the average yearly increase for the Bloomington field being worth $9.90 an acre, at the lower prices, as a sixteen-year average. This is $6.40 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it is applied on the Sibley and the Bloomington fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying nitrogen, a liberal use of clover or other legume is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

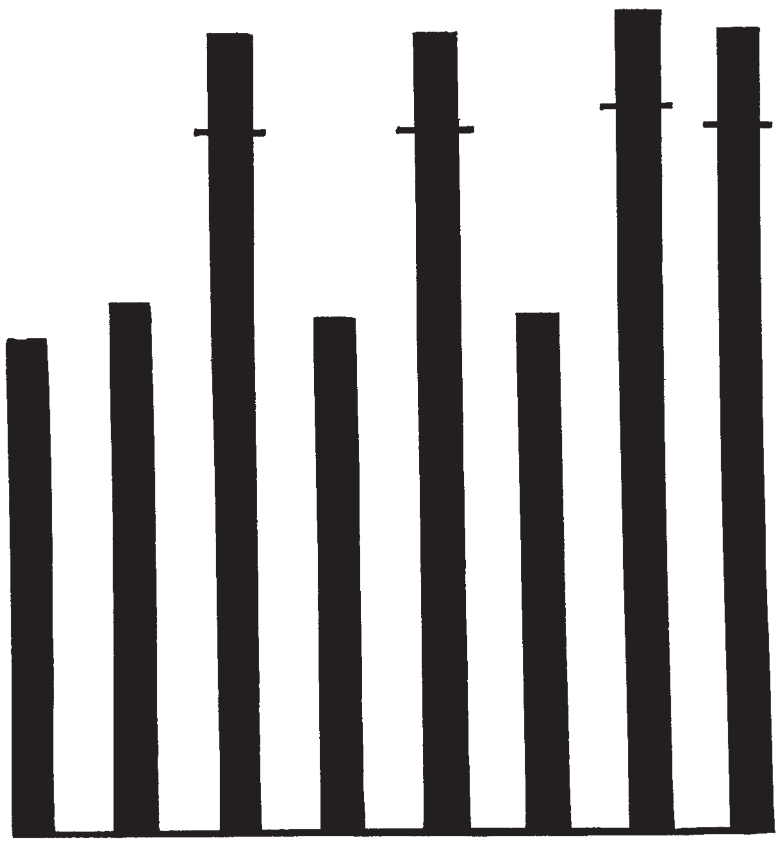
From the soil of the best treated plots on the Bloomington field, 204 pounds per acre of phosphorus, as an average, has been removed in the fifteen crops.

TABLE 10.—VALUE OF CROPS PER ACRE IN SIXTEEN YEARS, BLOOMINGTON FIELD

Plot	Soil treatment applied	Total value of fifteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$299.55	$419.37
102	Lime	292.20	409.08
103	Lime, residues	312.80	437.92
104	Lime, phosphorus	470.25	658.35
105	Lime, potassium	303.99	425.59
106	Lime, residues, phosphorus	471.19	659.67
107	Lime, residues, potassium	307.20	430.08
108	Lime, phosphorus, potassium	485.01	679.01
109	Lime, residues, phosphorus, potassium	474.34	664.08
110	Residues, phosphorus, potassium	434.95	608.93
	Value of Increase per Acre in Fifteen Crops		
	For residues	$20.60	$28.84
	For phosphorus	178.05	249.27
	For *residues* and phosphorus over phosphorus	.94	1.32
	For *phosphorus* and residues over residues	158.39	221.75
	For *potassium*, residues, and phosphorus over residues and phosphorus	3.15	4.41

[1]Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.
[2]Wheat at $1.40 a bushel, corn at 70 cents, oats at 56 cents, and hay at $14 a ton.

This is equal to 17 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for ninety years, they would require as much phosphorus as now constitutes the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus has been applied, the crops have removed only 132 pounds of phosphorus during the same period, which is equivalent to only 11 percent of the total amount (1,200 pounds) present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1917, as an average of all plots where it has been used, has amounted to 400 pounds per acre and has cost $56.[1] This has paid back $171.15, or 300 percent on the investment; whereas potassium, used in the same number of tests has paid back only $6.02 per acre in the sixteen years, or about 15 percent of its normal cost, leaving a net loss of 85 cents from each dollar invested in potassium. Are not these results to be expected from the composition of such soil and the requirement of crops? (See Table 2; also Table A in the Appendix.)



102	103	104	105	106	107	108	109
0	R	P	K	RP	RK	PK	RPK
$292.20	$312.80	$470.25	$303.99	$471.19	$307.20	$485.01	$474.34

PLATE 7.—CROP VALUES FOR SIXTEEN YEARS, BLOOMINGTON EXPERIMENT FIELD
(R=residues; P=phosphorus; K=potassium, or kalium)

[1]This is based on $35 a ton for steamed bone meal; in earlier years the price was about $25.

Nitrogen was applied to the residue plots of this field, in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover (except the seed) was plowed under on the five residue plots. Straw and corn stalks have also been returned to these plots, beginning with 1908. The effect of returning these residues to the soil has been appreciable since 1908 (an average increase on Plot 106 of 2.0 bushels of wheat, 7.2 bushels of corn, and 13.0 bushels of oats) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the sixteen years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil. The roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

Plate 7 shows graphically the relative values of the fifteen crops for the years 1902 to 1917, for the eight comparable plots, Nos. 102 to 109. The

TABLE 11.—FERTILITY IN THE SOILS OF CHAMPAIGN COUNTY, ILLINOIS
Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils (900, 1100)								
926 / 1126	Brown silt loam ...	72 330	6 390	1 690	74 080	25 050	20 510		50
920 / 1120	Black clay loam....	65 500	6 140	2 620	69 600	30 240	34 230	Often	
928 / 1128	Brown-gray silt loam on tight clay	27 080	3 240	1 440	64 980	14 380	9 060		3 040
1121	Drab clay loam....	54 440	5 420	2 180	72 580	28 660	30 740	Often	Often
1160	Brown sandy loam.	44 240	3 800	1 560	54 200	13 760	12 400		400
	Upland Timber Soils (900, 1100)								
934 / 1134	Yellow-gray silt loam............	20 440	2 410	1 410	72 410	23 950	14 410		1 840
935 / 1135	Yellow silt loam...	12 560	1 120	1 720	76 880	15 600	12 040		160
1164	Yellow-gray sandy loam...........	16 080	1 160	1 240	60 080	8 680	10 440		40
	Terrace Soils (1500)								
1536	Yellow-gray silt loam over sand or gravel.........	16 080	2 180	1 940	74 620	20 060	11 580		3 560
1527	Brown silt loam over sand or gravel	63 040	5 920	2 080	72 960	19 600	14 080		40
1560	Brown sandy loam.	48 720	4 400	1 600	66 040	12 880	15 560		40
	Swamp and Bottom-Land Soils (1400)								
1454	Mixed loam.......	76 200	7 180	2 260	77 180	23 680	26 540		Often
1401	Deap peat[1]	650 500	53 160	2 100	13 480	11 800	66 600	15 040	
1402	Medium peat on clay[1]...........	181 400	14 260	780	34 880	16 200	21 320		60

[1]Amounts reported are for 2 million pounds of deep peat and medium peat.

cost of the phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. Plot 106, which receives the most practical treatment for permanent agriculture (RLP), has produced a total value in sixteen years which is only 94 cents above that from Plot 104 (LP). (See also table on last page of cover.)

THE SUBSURFACE AND SUBSOIL

In Tables 11 and 12 are recorded the amounts of plant food in the subsurface and the subsoil of the different types of soil in Champaign county, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the most common upland soils are usually acid in the surface and subsurface and sometimes contain no limestone in the subsoil. These tables also show great stores of potassium and only limited amounts of phosphorus, in agreement with the data for the surface stratum (Table 2).

TABLE 12.—FERTILITY IN THE SOILS OF CHAMPAIGN COUNTY, ILLINOIS
Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils (900, 1100)								
926 / 1126	Brown silt loam ...	33 510	3 920	2 250	118 690	56 850	49 010	Often	Often
920 / 1120	Black clay loam...	29 110	3 330	3 230	109 130	62 330	76 600	Often	
928 / 1128	Brown-gray silt loam on tight clay	21 240	2 730	2 130	102 840	33 810	17 760		1 590
1121	Drab clay loam....	37 470	3 780	2 610	111 030	62 580	80 370	Often	Often
1160	Brown sandy loam.	20 040	1 800	1 740	81 540	21 180	18 480		1 680
	Upland Timber Soils (900, 1100)								
934 / 1134	Yellow-gray silt loam............	17 860	2 700	2 340	113 660	51 660	37 260	Often	Often
935 / 1135	Yellow silt loam...	14 040	1 440	2 940	108 060	28 140	21 180		720
1164	Yellow-gray sandy loam...........	11 400	1 020	1 800	82 560	14 220	15 300		300
	Terrace Soils (1500)								
1536	Yellow-gray silt loam over sand or gravel..........	15 810	2 610	2 730	134 340	61 830	34 950	Often	Often
1527	Brown silt loam over sand or gravel	38 100	3 840	2 460	99 840	33 420	20 400		600
1560	Brown sandy loam	21 180	2 100	1 800	105 240	23 940	19 260		60
	Swamp and Bottom-Land Soils (1400)								
1454	Mixed loam.......	39 690	3 990	2 010	111 990	31 110	32 760		60
1401	Deep peat[1]........	248 160	17 880	1 290	50 160	21 150	32 730	28 080	
1402	Medium peat on clay............	218 760	16 140	2 640	128 520	101 100	135 420	437 280	

[1]Amounts reported are for 3 million pounds of deap peat.

INDIVIDUAL SOIL TYPES

(a) Upland Prairie Soils

The upland prairie soils of Champaign county occupy 911 square miles, or 92.2 percent of the area of the county. They are black or brown in color, owing to their large content of organic matter.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses that once covered them, whose network of roots was protected from complete decay by the imperfect aeration resulting from the covering of fine soil material and the moisture it contained. On the native prairies, the tops of these grasses were usually burned or decayed almost completely, so that they added very little organic matter to the soil. From a sample of virgin sod of "blue stem," one of the most common prairie grasses, it has been determined that an acre of this soil to a depth of 7 inches contained 13.5 tons of roots. Many of these roots died each year and by partial decay formed the humus of these dark prairie soils.

Brown Silt Loam (1126, *or* 926 *on moraines*)

Brown silt loam is the most important as well as the most extensive soil type in Champaign county. It covers an area of 720 square miles (460,800 acres), or 72.9 percent of the county. This type occupies the slightly undulating to rolling areas of the prairie land, including both morainal and intermorainal areas. Many of these areas are well surface-drained, tho many need artificial drainage. The morainal areas are sometimes so rolling that considerable care is required to prevent erosion. Altho brown silt loam is normally a prairie soil, yet in some limited areas forests have recently invaded it, but not changed it materially. These forests consist quite largely of black walnut, wild cherry, hackberry, ash, hard maple, and elm. A black-walnut soil is recognized generally by farmers as being one of the best timber soils, but this is because of the fact that it still contains a large amount of organic matter, characteristic of prairie soils. After the growth of several generations of trees, the organic matter would become so reduced that the soil would then be classed as a timber type.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying on the one hand to black as it grades into black clay loam (1120), and on the other hand to grayish brown or yellowish brown as it grades into the timber type, yellow-gray silt loam (934 or 1134). In physical composition it varies to some extent, but it is normally a silt loam, containing from 65 to 80 percent of silt, together with some sand, and from 10 to 15 percent of clay. The amount of clay increases as the type approaches black clay loam (1120), and becomes greatest in the level, poorly drained areas. The amount of sand varies from 15 to 25 percent.

The organic-matter content varies from about 4 to 6 percent, with an average of 4.9 percent, or 49 tons per acre. The amount is less in the more rolling areas than in the low and poorly drained parts, owing not only to the fact that less vegetation grows on the drier, rolling areas, but also to the fact that when incorporated with the soil much of it is removed by erosion and undergoes greater decomposition, because of better aeration and less moisture. Where the type passes into the yellow-gray silt loam (934 or 1134), the organic-matter content becomes less, while it is greater in the low, swampy tracts, where the grasses grew more luxuriantly, and where the large moisture content furnished conditions more favorable for the preservation of organic matter of the grass roots.

The natural subsurface is represented by a stratum varying from 6 to 16 inches in thickness. On the moraines, the stratum is thin and light in color. It varies in physical composition in the same way as the surface soil, but it usually contains a slightly larger amount of clay, especially as it approaches the black clay loam (1120). In both color and depth the stratum varies with the topography, being lighter in color as well as shallower on the more rolling areas and where the type grades into yellow-gray and yellow silt loam (1134 or 1135). The amount of organic matter varies with depth, but the average for this stratum (which is twice the thickness of the surface soil as it is sampled) is 3.2 percent, or 64 tons per acre.

The natural subsoil begins at a depth of 12 to 23 inches beneath the surface, and extends to an indefinite depth, but is sampled from 20 to 40 inches. It varies with the topography both in color and texture; with depth it becomes slightly coarser. It consists of a yellow or drabbish mottled yellow, clayey silt or silty clay, plastic when wet. Where the drainage has been good, it is of a

PLATE 8.—A VERY WASTEFUL WAY OF DISPOSING OF CORN STALKS. NITROGEN IS LOST, AND AT PRESENT PRICES (1918), THIS MEANS A LOSS OF MORE THAN $4 FOR EACH TON OF STALKS BURNED. THE ORGANIC MATTER, WHICH HAS A HIGH VALUE IN KEEPING THE SOIL IN GOOD PHYSICAL CONDITION, IS ALSO LOST

bright to pale yellow color. With poor drainage, it approaches a drab or olive color with pale yellow mottlings or a yellow color with mottlings of drab.

Each of the three strata is pervious to water, so that drainage takes place with little difficulty.

On the more rolling moraines the glacial drift is sometimes encountered less than 30 inches from the surface, owing to the removal of part of the fine loessial material by erosion. Where the drift is quite compact, as is occasionally the case, the subsoil is somewhat inferior, owing to its less pervious character. This condition, however, does not occur very often nor over very large areas, since most of the drift is pervious and some of it is quite gravelly. Occasionally glacial till forms the surface soil, and where this occurs the soil may be quite gravelly. Gravel may sometimes be found in the surface soil in draws where the small pebbles have been washed down during heavy rains from the adjoining higher land of exposed glacial drift.

In the eastern part of the county in Township 19 North, Ranges 10 and 11 East of 3d P. M., and Range 14 West of 2d P. M., this type contains more fine and medium sand than usual, and even some very small areas of sandy loam, too small to be shown on the map as a separate type. These areas are not objectionable; in fact the small increase in sand is even desirable as it improves the working qualities of the soil.

When the virgin brown silt loam was first cropped, the soil was in fine tilth, worked easily, and large crops could be grown with much less work than now. Continuous cropping, however, to corn or corn and oats with the burning of corn stalks, stubble, grass, and in many cases even straw, has destroyed the tilth in a great measure and now the soil is more difficult to work, washes badly, runs together, and bakes more. Unless the moisture conditions are very favorable, the ground plows up cloddy, and unless well-distributed rains follow, a good seed bed is difficult to produce. The clods may remain all season. Much plant food is locked up in them and thus made unavailable, so that the best results cannot be obtained. This condition of poor tilth may become serious if the present methods of management continue; it is already one of the factors that limit crop yields. The remedy is to increase the organic-matter content by plowing under every available form of vegetable material, such as farm manure, corn stalks, straw, clover, stubble, and even weeds.

The deficiency of organic matter in the soils is shown by the way the fall-plowed land runs together during the winter. Much more work is required to produce a seed bed than was formerly the case. The result is that corn is frequently planted in poorly prepared seed beds and as a consequence it "fires" badly. Fall-plowed land should be disked early and deep for the purpose of conserving moisture, increasing temperature, and making plant food available.

The addition of fresh organic matter is not only of great value in improving the physical condition of this type of soil, but it is of even greater importance because of its nitrogen content and because of its power, as it decays, to liberate potassium from the inexhaustible supply in the minerals of the soil and phosphorus from the phosphate contained in or applied to the soil.

For permanent, profitable systems of farming on brown silt loam, phosphorus should be applied liberally, and sufficient organic matter should be pro-

PLATE 9.—A GOOD SEED BED FOR OATS PRODUCED BY THE DISK AND SPIKE-TOOTH HARROW WHERE THE STALKS ARE LEFT ON THE SURFACE

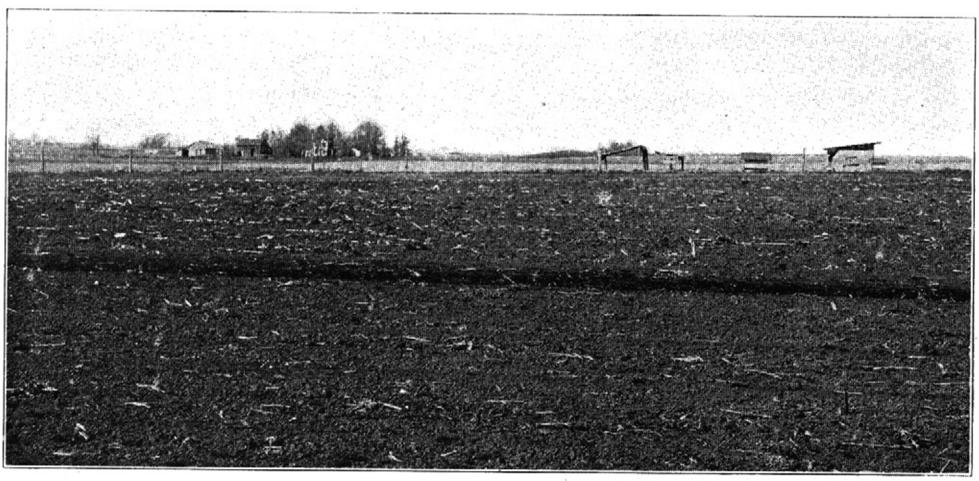


PLATE 10.—A GOOD SEED BED FOR CORN WHERE THE STALKS HAVE BEEN TURNED UNDER

vided to furnish the necessary amount of nitrogen. On the ordinary type, limestone is already becoming deficient. An application of two tons of limestone and one-half ton of fine-ground rock phosphate per acre every four years, with the return to the soil of all manure made from a rotation of corn, corn, oats, and clover, will maintain the fertility of this type, altho heavier applications of phosphate may well be made during the first two or three rotations, and the first application of limestone may well be four tons per acre. If grain farming is practiced, the rotation may be wheat, corn, oats, and clover, with an extra seeding of clover (preferably sweet clover) as a cover crop in the wheat, to be plowed under late in the fall or in the following spring for corn; and most

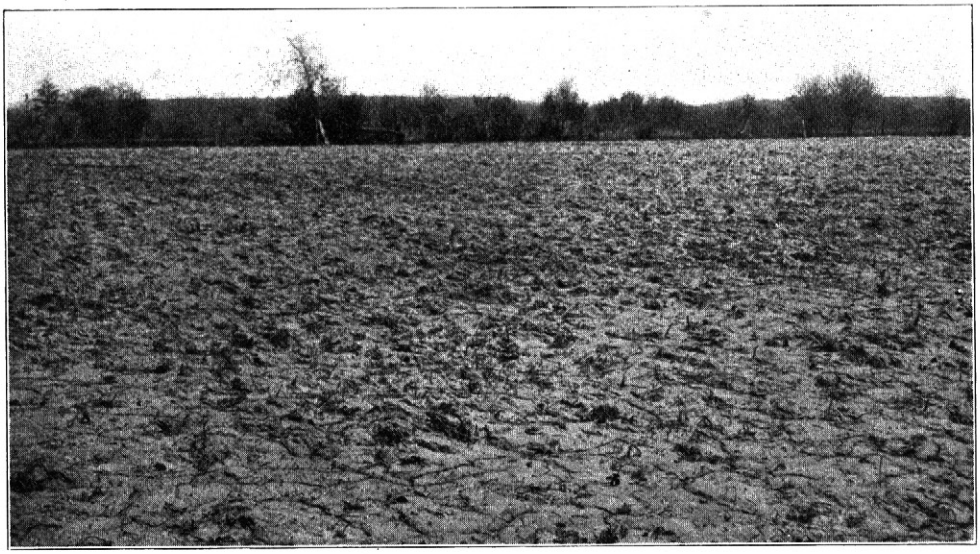


PLATE 11.—A DEFICIENCY OF ORGANIC MATTER WILL CAUSE FALL-PLOWED LAND TO RUN TOGETHER AND CRACK

of the crop residues, including the clover chaff from the seed crops, should also be plowed under. In either system, alfalfa may be grown on a fifth field and moved every five years, the hay being fed or sold. In live-stock farming, the regular rotation may be extended to five or six years by seeding both timothy and clover with the oats, and pasturing one or two years. Alsike may well replace red clover at times, in order to avoid clover sickness. (For results secured in field experiments on brown silt loam, see the preceding pages.)

Black Clay Loam (1120, *or* 920 *on Moraines*)

Black clay loam represents the flat prairie. It is sometimes called "gumbo" because of its sticky character. Its formation in the flat, poorly drained areas is due to the accumulation of organic matter and to the washing in of clay and fine silt from the slightly higher adjoining lands. This type occupies 176.47 square miles (112,940 acres), or 17.86 percent of the entire area of the county. It is so flat that dredge ditches and tile drainage are often required to solve one of the most difficult problems in its management.

The surface soil, 0 to 6⅔ inches, is a black, plastic, granular clay loam, varying locally to a black, clayey silt loam. It contains, on an average, 6.3 percent of organic matter, or 63 tons per acre, but it varies considerably from this average. In physical composition, this stratum varies somewhat as it grades into other types. As it passes toward brown silt loam, which nearly always surrounds it, it becomes more silty. In some of the former sloughs, the water or floating ice has carried considerable small gravel which has been deposited in sufficient abundance over small areas to form a gravelly black clay loam.

The subsurface stratum has a thickness of 10 to 16 inches and varies from a black to a brownish gray clay loam, usually somewhat heavier than the surface soil. The average amount of organic matter is 2.8 percent, or 56 tons per acre. The lower part of this stratum frequently is a drab or yellowish drab silty clay. The stratum is quite pervious to water, owing to the jointing or checking from shrinkage in times of drouth and to the action of crayfish and other animals.

The subsoil to a depth of 40 inches varies from a drab to a yellowish drab silty clay. As a rule, the iron is not highly oxidized, because of poor drainage and lack of aeration. Concretions of carbonate of lime are frequently found. The perviousness of the subsoil is about the same as that of the subsurface and is due to the same causes. When thrown out on the surface where wetting and drying may take place, the subsoil soon breaks into small cubical masses. Gravel is frequently present.

Black clay loam presents many variations. In Champaign county as elsewhere, the boundary lines between it and the brown silt loam are not always distinct. In some areas topography is a great help in locating the boundary, but in other places there may be an intermediate zone of greater or less width. The washing in of silty material from the surrounding higher lands, especially near the edges of the areas, modifies the character of the soil, giving the surface a silty character. This change is taking place more rapidly now, with the annual cultivation of the soil, than formerly, when washing was largely prevented by prairie grasses. Part of the areas mapped as black clay loam grade toward drab clay loam, the black soil not being very deep, and passing into a drab or yellowish drab color at a depth of 10 to 14 inches.

Occasional small patches of alkali soil occur in the black clay loam areas. These spots are indicated by the fact that oats lodge badly and corn makes a poor growth, usually turning greenish yellow, yellow, or brown. If the amount of alkali is large, the corn may not grow over two or three feet high and presents a bushy appearance. If it reaches almost normal height, it does not produce much grain. This condition is due to an excess of injurious carbonates in the soil. The remedy is to drain the land thoroly and to turn under horse manure, coarse stable manure, straw, corn cobs, or green manure. The straw of lodged oats may well be plowed under for corn. Drainage is the first requirement in the management of this type. Altho it usually has but little slope, yet because of its perviousness it is easily tile-drained. Keeping the soil in good physical condition is very essential, and thoro drainage helps to do this to a great extent. As the organic matter is destroyed by cultivation and nitrification, and as the limestone is removed by cropping and leaching, the soil becomes poorer in physical condition, and as a consequence it becomes more difficult to work. Both organic matter and limestone tend to develop granulation. The former should be maintained by turning under manure or such crop residues as corn stalks and straw, and by the use of clover and pasture in rotations. Ground limestone should be applied when needed to keep the soil sweet. It should be remembered that the difficulty of working clay soils is in proportion to their deficiency in organic matter.

While black clay loam is one of the best soils in the state, yet the clay and humus which it contains give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times, especially during drouth. When the soil is wet, these constituents expand, and when the moisture evaporates or is used by crops, they shrink. This results in the formation of cracks, sometimes as much as two or more inches in width at the surface and extending with lessening width to two or three feet in depth. During the drouth of 1914, the cracks were so large and deep that in many cases a one-inch auger could be forced into them, without turning, to a depth of more than two feet. These cracks allow the soil strata to dry out rapidly, and as a result the crop is injured thru lack of moisture. They may do considerable damage by "blocking out" hills of corn and severing the roots. While cracking may not be prevented entirely, good tilth with a soil mulch will do much toward that end. Both for aeration and for producing a mulch for conserving moisture, cultivation is more essential on this type than on the brown silt loam. It must be remembered, however, that cultivation should be as shallow as possible, in order to prevent injury to the roots of the corn. (See Bulletin 181, Soil Moisture and Tillage for Corn.)

At Urbana, on the South Farm of the University of Illinois, a series of plots devoted chiefly to variety tests and other crop-production experiments extends across an area of black clay loam. Where rock phosphate has been applied at the rate of 500 pounds an acre a year in connection with crop residues, in a four-year rotation of wheat, corn, oats, and clover (or soybeans), the value of the increase produced per ton of phosphate has been, in three successive rotation periods, $3.04, $6.71, and $9.26, respectively, at the lower prices for produce, or $4.26, $9.40, and $12.96, respectively, at the higher prices. In the live-stock system, the phosphorus naturally supplied in the manure, supplemented by that liberated from this fertile soil, has thus far been nearly sufficient to meet the crop requirements; the increase in crop values per ton of phosphate applied having been, as an average for the twelve years, only $3.26 at the lower prices, or $4.52 at the higher prices. These returns are less than half the cost of the phosphorus applied, and in some seasons no benefit appears.

This type is rich in magnesium and calcium, and in the Wisconsin glaciation it sometimes contains plenty of carbonates. With continued cropping and leaching, applications of limestone will ultimately be needed.

Drab Clay Loam (1121)

The drab clay loam occupies 9.58 square miles (6,131 acres), or .97 percent of the area of the county. The topography is flat, or about the same as that of the black clay loam (1120).

The surface soil, 0 to 6⅔ inches, is a clay loam, usually a little heavier than black clay loam (1120), but not so dark and in some cases it may have a slightly grayish color. The organic-matter content averages 4.9 percent, or 49 tons per acre. Typically it should contain about 4 percent, but it grades into black clay loam, and this increases the amount. The change to drab clay loam is usually noticeable immediately beneath the surface soil.

The subsurface soil is a stratum of indefinite thickness, owing to the fact that it is very difficult to determine where the natural subsurface ends and the subsoil begins, there being no distinct change in color or texture. In color the subsurface varies from a brown to a drab or olive; in texture it is a plastic, pervious clay loam. The organic-matter content averages 46 tons per acre, which is less than for either black clay loam or brown silt loam.

The subsoil is a dull yellow or olive-colored silty clay. Limestone concretions sometimes occur in this stratum.

In general this type should receive the same treatment as black clay loam, except that greater effort should be made to maintain the content of organic matter, since this type is lower in that constituent.

Brown-Gray Loam on Tight Clay (928, 1128)

Brown-gray silt loam on tight clay occurs in small areas thruout the county, many of which are not large enough to be shown on the map. The total area is 4.11 square miles (2,630 acres) or .42 percent of the total area of the county. The larger areas are found in the south-central part of the county, near the Embarrass river. This type occurs as a shelf between the overflow land and the upland. In some areas it is underlain by a stratum of gravel at a depth of five to seven feet. This gravel stratum is not very thick. The topography is flat and natural drainage is poor.

The surface soil, 0 to 6⅔ inches, is a grayish brown to gray silt loam. It varies in color with the content of organic matter. Near brown silt loam it is of a darker color, while in some spots it is gray. This stratum contains about 3.3 percent of organic matter, or 33 tons per acre. It contains some fine sand and coarse silt, which give it a peculiar mealy or floury feel, but excellent texture. Some medium-sized gravel are found that have been brought up by crayfish.

The subsurface soil, 6⅔ to 18 inches, is a gray to a yellowish gray silt to silt loam, which contains 1.2 percent of organic matter. This stratum is very slowly pervious to water.

The subsoil is a gray to yellowish gray silt to clayey silt, a little less pervious, perhaps, than the subsurface. It begins at a depth of about 18 inches. When dry, this stratum becomes very hard and difficult to remove, except with a pick. The content of organic matter is .6 percent.

Naturally this soil is one of the poorest in the county, being wet and usually difficult to drain, comparatively low in organic matter and fertility, and decidedly acid. The first requirement is drainage, either by means of tile or surface ditches. The lines of tile must be placed closer together than in any other type in the county. The distance should not be over four rods.

This soil is the most acid of all the types in the county, and it is also quite deficient in phosphorus and nitrogen. It should have an initial application of about four tons of limestone and one ton of rock phosphate per acre. Afterward about one-half these amounts for each rotation will maintain the supply, altho the heavier applications of phosphate may well be continued for several rotations. The organic matter and nitrogen should be increased in every practical way, such as by turning under crop residues, manure, and clover. Deep-rooting crops are especially beneficial to this soil, since they aid drainage and deeper aeration. For this reason, mammoth and sweet clovers are recommended for this type. The soil runs together badly, and the application of limestone and the increase of organic matter will aid in preventing this. When fall-plowed, the soil becomes packed by spring almost as hard as it was before plowing. About the only advantages of fall plowing are that it turns under the organic matter so that it is partly decomposed by the time the crop is put in, and that it permits earlier working in the spring.

Brown Sandy Loam (1160)

Brown sandy loam occupies only 557 acres, or .09 percent of the area of the county. It occurs in small areas in the east-central part of the county representing old beach or shore lines of a temporary lake. The sand was blown up into low dunes that now constitute the sandy loam.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam, varying in sand content as well as in color. The tops of the low dunes or ridges are generally more sandy than the sides, owing to the fact that the fine material has been washed away. For the same reason the soil of these ridges is lighter in color. This stratum contains about 2.5 percent, or 25 tons of organic matter per acre.

The subsurface soil, 6⅔ to 15 inches, is a light brown sandy loam with 1.9 percent of organic matter, or 38 tons per acre.

The subsoil varies from a yellow clayey silt to a yellow sand.

This type is a very good soil, but it is low in nitrogen and distinctly acid. For its marked and profitable improvement liberal use should be made of limestone and legume crops. While the soil is not rich in phosphorus on the percentage basis, it is so porous that it affords a deep feeding range for plant roots, and hence additional supplies of phosphorus are not likely to be profitable until the present supply is reduced.

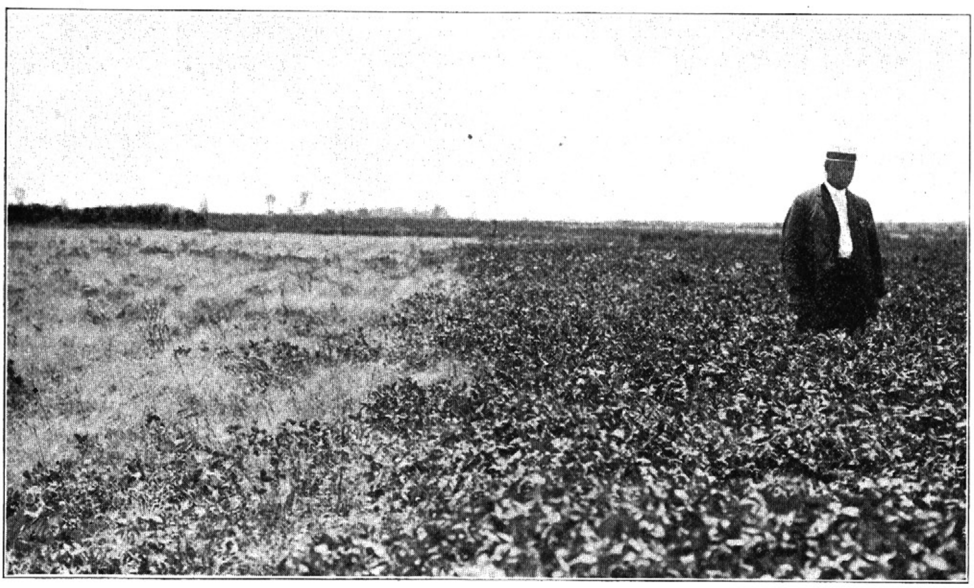


PLATE 12.—EFFECT OF ROCK PHOSPHATE AND LIMESTONE ON THE GROWTH OF CLOVER ON BROWN-GRAY SILT LOAM ON TIGHT CLAY. THE CHECK STRIP ON THE LEFT IS COVERED WITH GRASS AND WEEDS, THE CLOVER HAVING FAILED ALMOST ENTIRELY

(b) UPLAND TIMBER SOILS

The upland timber soils usually occur along streams, altho two exceptions are found in Champaign county where forests exist remote from streams. Timber soils are characterized by a yellow, yellowish gray, or gray color, due to their low organic-matter content resulting from the long-continued growth of forest trees. As the forests invaded the prairies, two effects were produced: (1) the shading by the trees prevented the growth of prairie grasses, the roots of which are mainly responsible for the large amount of organic matter in prairie soils; (2) the trees themselves added very little organic matter to the soil, for the leaves and fallen branches either decayed completely or were burned by forest fires. As a result the organic-matter content has been reduced to a low percentage.

Yellow-Gray Silt Loam (934, 1134)

Yellow-gray silt loam occurs in the outer timber belts along streams and in the less rolling of the timbered morainal areas. The type covers 45.16 square miles (28,902 acres), or 4.57 percent of the entire area of Champaign county. In topography it is sufficiently rolling for good surface drainage, without much tendency to wash if proper care is taken.

The surface soil, 0 to 6⅔ inches, is a yellow, yellowish gray, gray or brownish gray silt loam, having a floury feel. The more nearly level areas are gray in color, while the more rolling phase of the type has a yellow or brownish yellow color. As the type approaches brown silt loam, it becomes decidedly darker. The organic-matter content averages 2.2 percent, or 22 tons per acre, but it varies considerably with topography. As the type approaches brown silt loam, the organic-matter content amounts to as much as 2.5 percent, while as it approaches yellow silt loam, it diminishes to as low as 1.6 percent. In some places it is difficult to draw the line between long-cultivated brown silt loam and yellow-gray silt loam, because of the gradation between the types.

The subsurface stratum varies from 3 to 10 inches in thickness. It is usually a gray, grayish yellow, or yellow silt loam, somewhat pulverulent, but becoming more coherent and plastic with depth. The organic-matter content is about .9 percent, or 18 tons per acre.

The subsoil is a yellow or mottled grayish yellow, clayey silt or silty clay, somewhat plastic when wet, but friable when only moist, and pervious to water.

Owing to the removal by erosion of part of the loessial material, glacial drift is sometimes encountered at a depth of less than 40 inches. The glacial drift may be locally a very gravelly deposit, but usually it is a slightly gravelly clay.

A few small, level areas of a light gray color occur in this type, and here a tight and more or less compact clayey layer is found at a depth of 16 to 24 inches. None of these areas, however, are large enough to be shown on the map. Consequently they are included in the yellow-gray silt loam.

In the management of this yellow-gray silt loam, one of the most essential points is the maintaining or the increasing of organic matter. This is necessary in order to supply nitrogen and liberate mineral plant food, to give better tilth, to prevent "running together," and on some of the more rolling phases to prevent washing.

Another essential is that the acidity of the soil be neutralized by the application of ground limestone, so that clover, alfalfa, and other legumes may be grown more successfully. The initial application may well be 4 or 5 tons per acre, after which 2 tons per acre every four or five years will be sufficient. Since the soil is poor in phosphorus, this element should be applied, preferably in connection with farm manure or clover plowed under. In permanent systems of farming, fine-ground natural rock phosphate will be found the most economical form in which to supply the phosphorus, altho when prices are normal steamed bone meal or acid phosphate may well be used temporarily until plenty of decaying organic matter can be provided.

For definite results from the most practical field experiments upon typical yellow-gray silt loam, we must go down into "Egypt," where the people of Saline county, especially those in the vicinity of Raleigh and Galatia, have provided the University with a very suitable tract of this type of soil for a permanent experiment field. There, as an average of duplicate trials each year for the four years 1910 to 1913, the crop values from four acres were $27.99 from untreated land, $28.80 where organic manures were applied in proportion to the amount of crops produced, $50.07 where 6 tons per acre of limestone and organic manures were applied, and $51.66 with organic manures, limestone and rock phosphate—the wheat, corn, oats, and clover (or cowpeas or soybeans) grown in the rotation being valued at the lower prices heretofore mentioned. The corresponding values for the next four years[1] were $22.35 with no soil enrichment, $29.22 with organic matter, $54.37 with limestone and organic matter, and $57.27 with organic matter, limestone, and rock phosphate.

Owing to the low supply of organic matter, phosphorus produced almost no benefit, as an average, during the early years; but, with increasing applications of organic matter, the effect of phosphorus may become more apparent in subsequent crops. Of course the full benefit of a four-year rotation cannot be realized during the first four years. The farm manure was applied to one field each year, beginning with 1911, and the fourth field received no manure until the first year of the second rotation. Likewise, crop residues plowed under during the first rotation may not be fully recovered in subsequent increased yields until the second or third rotation period.

More recently the people of White county have furnished the University with a tract of yellow-gray silt loam near Enfield, on which experiments have been started. The crop values from four acres, as an average of the first four years (1913-1916), were $24.64 from unfertilized land, $28.25 with organic manures, $39.10 with manures and limestone, and $45.10 with manures, limestone, and rock phosphate; and the corresponding average values for 1917 were $30.58 with no treatment, $35.08 with organic manures, $83.35 with manures and limestone, and $89.91 with manures, limestone, and phosphate. (These values are based on the higher prices mentioned above and with the exceptions noted, are the averages of data from two systems of farming, which include the use of farm manure in one and of green manures and crop residues in the other.)

While limestone is the material first needed for the economic improvement of the more acid soils of southern Illinois, with organic manures and phosphorus

[1]Wheat was destroyed by hail in 1915, and the test for legumes for 1916 is not in duplicate.

TABLE 13.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD
YELLOW GRAY SILT LOAM, UNDULATING TIMBERLAND; LATE WISCONSIN GLACIATION

Plot	Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Clover 1913[2]	Wheat 1914
		Bushels or tons per acre												
101	None	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3	.50	30.8
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5	.60	30.0
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4	([3])	40.8
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1	1.32	54.2
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8	.72	34.0
106	Lime, nitrogen, phosphorus	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9	([3])	41.3
107	Lime, nitrogen, potassium	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9	([3])	43.2
108	Lime, phosphorus, potassium	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9	1.60	46.0
109	Lime, nitrogen, phosphorus, potassium	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9	([3])	41.0
110	Nitrogen, phosphorus, potassium	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1	([3])	37.8
		Increase: Bushels or Tons per Acre												
	For nitrogen	1.2	1.9	-10.0	7.5	6.3	-3.1	-1.3	1.3	-1.6	-14.2	6.9		10.8
	For phosphorus	5.0	14.7	-.3	25.5	25.9	3.9	9.3	11.6	3.8	12.8	31.6	.72	24.2
	For potassium	3.1	11.3	-3.1	11.4	3.4	3.4	.9	1.8	1.6	-4.2	1.3	.12	4.0
	For nitrogen, phosphorus over phosphorus	6.5	9.1	3.4	-20.6	1.9	7.5	-21.8	10.5	-.8	-.4	2.2		-12.9
	For phosphorus, nitrogen over nitrogen	10.3	21.9	13.1	-2.6	21.5	14.5	-11.2	20.8	4.6	26.6	22.5		.5
	For potassium, nitrogen, phosphorus over nitrogen, phosphorus	4.6	6.4	16.0	2.8	6.6	10.5	2.8	-3.3	-3.0	7.2	-15.0		-.3

[1]Crop residues in place of commercial nitrogen after 1911.
[2]Figures in parentheses indicate bushels of seed; the others, tons of hay.
[3]No seed produced: clover plowed under on these plots.

to follow in order, the less acid soils of the central part of the state are first in need of phosphorus, altho organic matter and limestone must also be provided for permanent and best results.

Table 13 shows in detail thirteen years' results from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. In acidity this type in Champaign county is intermediate between the similar soils in Saline or White and Lake counties, but no experiment field has been conducted on this important soil type in the early Wisconsin glaciation, in which Champaign county is located.

The Antioch field was started in order to learn as quickly as possible what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements were all added in commercial form until 1911, after which the use of commercial nitrogen was discontinued and crop residues were substituted in its place. (See report of Urbana field, page 9, for further explanations.) Only a small amount of lime was applied at the beginning, in harmony with the teaching which was common at that time; furthermore, Plot 101 proved to be abnormal, so that no conclusions can be drawn regarding the effect of lime. In order to ascertain the effect produced by additions of the different elements singly, Plot 102 must be regarded as the check plot. Three other comparisons are also possible to determine the effect of each element under different conditions.

As an average of forty tests (four each year for ten years), liberal applications of commercial nitrogen produced a slight decrease in crop values; but as an average of thirteen years each dollar invested in phosphorus paid back $2.59 (Plot 104), while potassium applied in addition to phosphorus (Plot 108) produced no increase, the crops being valued at the lower prices used in the tabular statement. Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost

TABLE 14.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, ANTIOCH FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$193.03	$270.24
102	Lime	171.06	239.48
103	Lime, nitrogen	178.15	249.40
104	Lime, phosphorus	288.85	404.40
105	Lime, potassium	198.40	277.76
106	Lime, nitrogen, phosphorus	256.31	358.82
107	Lime, nitrogen, potassium	190.77	267.08
108	Lime, phosphorus, potassium	287.65	402.70
109	Lime, nitrogen, phosphorus, potassium	273.18	382.44
110	Nitrogen, phosphorus, potassium	280.88	393.24

Value of Increase per Acre in Thirteen Years

For nitrogen	$ 7.09	$ 9.92
For phosphorus	117.79	164.92
For *nitrogen* and phosphorus over phosphorus	-32.54	-45.58
For *phosphorus* and nitrogen over nitrogen	78.16	109.42
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	16.87	23.62

[1]Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.
[2]Wheat at $1.40 a bushel, corn at 70 cents, oats at 56 cents, hay at $14 a ton.

complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus, the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase.

From a comparison of the results from the Urbana, Sibley, and Bloomington fields, we must conclude that better yields are to be secured by providing nitrogen by means of farm manure or legume crops grown in the rotation than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course the atmosphere is the most economical source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow Silt Loam (935, 1135)

Yellow silt loam covers 3.06 square miles (1,958 acres) and constitutes .31 percent of the entire area of the county. It occurs as hilly and badly eroded land on the inner timber belts adjacent to the streams, usually only in narrow, irregular strips with arms extending up the small valleys. In topography it is very rolling, and in most places so badly broken that it should not be cultivated because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow, pulverulent silt loam. It varies greatly in color and texture, owing to recent washing. In places the natural subsoil may be exposed. This exposure gives the surface a decidedly yellow color. When freshly plowed the soil appears yellow or brownish yellow, but when it becomes dry after a rain, it is of a grayish color. In some places the surface soil is formed from glacial drift, but this is only on very limited areas and on the steepest slopes. The organic-matter content is the lowest of any type in the county, averaging only 1.5 percent, or 15 tons per acre.

The subsurface varies from a yellow silt loam to a yellow clayey silt loam, and on the steepest slopes may consist of weathered glacial drift. The thickness of the stratum varies from 5 to 12 inches, depending on the amount of recent erosion. The organic-matter content amounts to only 12 tons per acre.

The subsoil consists normally of a yellow clayey silt, but in some areas it may be composed entirely of glacial drift.

The first and most important thing in the management of this type is the prevention of general surface washing and gullying. If the land is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible and allow pasture and meadow most of the time. If tilled, the land should be plowed deeply and contours should be followed as nearly as possible in plowing, planting, and cultivating. Furrows should not be made up and down the slopes. Every means should be employed to maintain and increase the organic-matter content. This will help hold the soil and keep it in good physical condition so that it will absorb a large amount of water and thus diminish the run-off.

Additional treatment recommended for this yellow silt loam is the liberal use of limestone wherever cropping is practiced. This type is quite acid; and the limestone, by correcting the acidity of the soil, is especially beneficial to the clover grown to increase the supply of nitrogen. Where this type has been long cultivated and thus exposed to surface washing, it is particularly deficient in nitrogen; indeed, on such lands the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two-pot culture experiments reported in Tables 15 and 16, and shown photographically in Plates 13 and 14.

In one experiment, a large quantity of the typical worn hill soil was collected from two different places. Each lot of soil was thoroly mixed and put in ten four-gallon jars. Wheat was planted in one series and oats in the other.[1] Ground limestone was added to all the jars except the first and last in each set, those two being retained as control, or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 15.

As an average the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield were to be expected, because of differences in the individuality of seed or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

The question arises next, where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizers would cost too much; indeed, under average conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

But there is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply of it, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa, cowpeas, and soybeans are not only worth raising for their own sake, but they have the power to secure nitrogen from the atmosphere if the soil contains the essential minerals and the proper nitrogen-fixing bacteria.

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used for wheat in the former experiment. The results are reported in Table 16.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms

[1]Soil for wheat pots from loess-covered unglaciated area, and that for oat pots from upper Illinoisan glaciation.

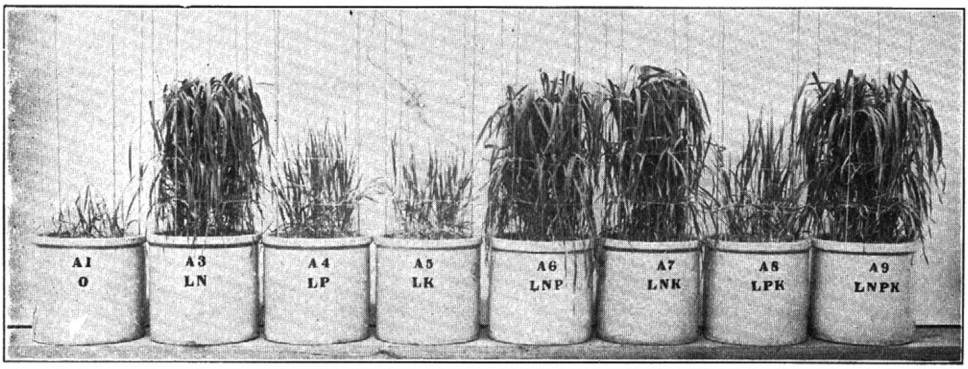


PLATE 13.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 15)

TABLE 15.—CROP YIELDS IN POT-CULTURE EXPERIMENTS WITH YELLOW SILT LOAM OF WORN HILL LAND
(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

that reported in Table 15 in showing the very great need of nitrogen for the improvement of this type of soil,—and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care. As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with erosion, which is sure to occur to some extent, the phosphorus supply will be renewed from the subsoil.

Probably the best legumes for this type of soil are sweet clover and alfalfa. On soil deficient in organic matter sweet clover grows better than almost any other legume, and the fact that it is a very deep-rooting plant makes it of value in increasing organic matter and preventing washing. Worthless slopes that have been ruined by washing may be made profitable as pasture by growing sweet clover. The blue grass of pastures may well be supplemented by sweet clover

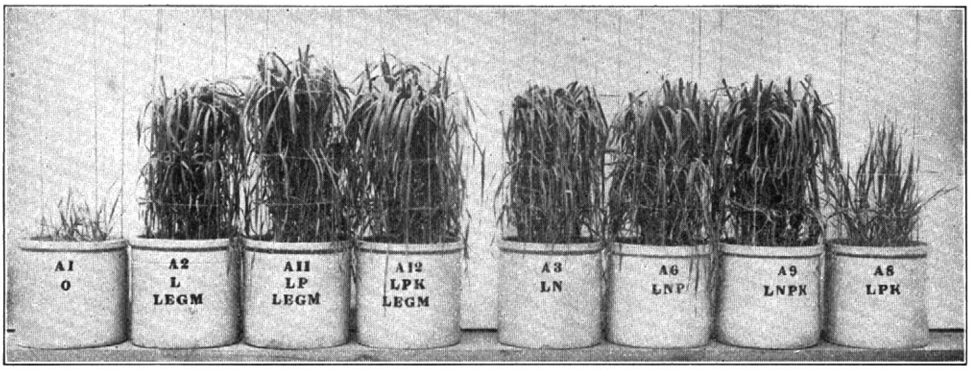


PLATE 14.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 16)

TABLE 16.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS

(Grams per pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

and alfalfa, and a larger growth obtained, because the legumes provide the necessary nitrogen for the blue grass.

To get alfalfa well started requires the liberal use of limestone, thoro inoculation with the proper nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (about 5 tons) should be applied after plowing and should be mixed with the surface soil in the preparation of the seed bed. The special purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Yellow-Gray Sandy Loam (1164)

A small area of yellow-gray sandy loam, comprizing about 70 acres, occurs near Glover. This was once covered with forest growth.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish gray sandy loam, containing 1.7 percent of organic matter, or 17 tons per acre.

The subsurface soil is a yellow sandy loam somewhat variable in physical composition. It contains .7 percent of organic matter.

The subsoil varies from a yellow clay or clayey silt to a sand.

For the improvement of this type of soil, ground limestone and organic manures are the only materials advised. With the deep feeding range afforded the plant roots, marked improvement can be made without the addition of phosphorus or potassium. The initial application of ground limestone may well be 4 or 5 tons per acre, and 6 or 8 tons will give still better results, especially for the production of alfalfa or sweet clover. Of course large use should be made of legume crops. Cowpeas and soybeans are both good crops for such land; they may be grown and plowed under in place of manure in preparing the land for alfalfa or other crops. (See also pages 482-483 of Bulletin 193, "Summary of Illinois Soil Investigations," which will be sent upon request.)

(c) TERRACE SOILS

Terrace soils were formed on terraces or old fills in valleys. The terraces owe their formation generally to the deposition of material from overloaded and flooded streams during the melting of the glaciers. The material varied from fine to coarse. These valleys were sometimes filled almost to the height of the upland. Later the streams cut down thru these fills and developed new bottom lands, or flood plains, at a lower level, leaving part of the old fill as a terrace. The lowest and most recently formed bottom land is called first bottom. The higher land no longer flooded (or very rarely at most) is generally designated as second bottom. Finer material later deposited on this sand and gravel of the fill now constitutes the soil. The terraces in Champaign county occur mostly along the Salt and Middle Fork, but there are small areas along a few of the other streams.

Yellow-Gray Silt Loam over Sand or Gravel (1536)

Yellow-gray silt loam over sand or gravel occurs in comparatively small areas along all the larger streams. The total area is 2.71 square miles (1,734 acres), or .27 percent of the area of the county. The topography is flat to slightly rolling.

The surface soil, 0 to 6⅔ inches, is a grayish yellow to brownish yellow silt loam, sometimes containing a perceptible amount of sand. It is pulverulent, but not granular. It contains about 2.1 percent of organic matter, or 21 tons per acre.

The subsurface soil is a yellow to brownish yellow silt loam, passing into a yellow silt at 12 to 14 inches. It contains .7 percent of organic matter.

The subsoil is a yellow silt, pervious and friable. The depth to gravel varies from 40 to 50 inches.

This type is well drained. The liberal use of ground limestone and legume crops is most important in its management. An increase of organic matter is very essential, as this constituent is so low that the soil "runs together" badly during rains. Phosphorus must also be applied for the best results.

Brown Silt Loam over Sand or Gravel (1527)

Brown silt loam over sand or gravel occurs principally in the northeastern part of the county along the Middle Fork. A few small areas are found along the Sangamon and Salt Fork. The total area is 2.41 square miles, or 1,542 acres. The depth to gravel varies from four to five feet, while the stratum of gravel is rarely over five feet thick. The topography is flat to slightly undulating.

The surface soil, 0 to 6⅔ inches, is a brown silt loam with slightly sandy local patches. It is not so dark as the upland brown silt loam, having only 3.6 percent of organic matter, or 36 tons per acre.

The subsurface is a pervious light brown silt loam, changing to yellow silt at a depth of 16 inches.

The subsoil is a yellow, slightly clayey silt, friable and pervious.

The treatment needed for this type is the same as that for upland brown silt loam (926, 1126).

Brown Sandy Loam (1560)

The area of brown sandy loam terrace is only 44 acres. It is lower in organic-matter content than the upland type, having only 1.7 percent. The same suggestion for its management will apply as for upland sandy loam (1160).

(d) SWAMP AND BOTTOM-LAND SOILS

Mixed Loam (1454)

Mixed loam occurs on the flood plains along the courses of the larger streams in Champaign county. With each flood deposits of sediment are left on these plains, thus renewing the soil. The total area of this type is 23.43 square miles (14,995), or 2.37 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a black to brown loam, varying from a silt loam to a sandy loam, but so badly mixed that it is impossible to indicate the separate areas on the map. Brown silt loam usually predominates. The organic-matter content averages 5.3 percent, or 53 tons per acre. It varies, however, from about 4.5 percent to 6.5 percent. The surface is usually in fine tilth.

The subsurface soil, 6⅔ to 20 inches, varies as much as the surface, but not necessarily in the same way. It contains 3.3 percent of organic matter.

The subsoil is usually much lighter than the subsurface, but sometimes the dark color extends almost to the full depth of 40 inches. The average amount of organic matter is 1.2 percent. All strata are pervious to water.

Most of this type in the county is in pasture, but, where the areas are sufficiently large, cropping is done, mostly to corn. This soil is usually well supplied with plant food, and, with the renewal by deposit from overflow, no other soil enrichment is advised.

Deep Peat (1401)

A few small areas of deep peat aggregating 90 acres are mapped in Champaign county. They occur in low, poorly drained areas in bottom lands, swamps, or low depressions on the moraines. With a single exception, they occur in the northeastern part of the county in Townships 21 and 22 North, and Ranges 10 and 11 East of 3d P. M., and 14 West of 2d P. M. The area constituting the exception is found in Section 26, Township 20 North, Range 9 East, in what

TABLE 17.—CORN YIELDS IN SOIL EXPERIMENTS, MANITO FIELD; TYPICAL DEEP PEAT SOIL (Bushels per acre)

Plot No.	Soil treatment for 1902	Corn 1902	Corn 1903	Soil treatment for 1904	Corn 1904	Corn 1905	Four crops
1	None	10.9	8.1	None	17.0	12.0	48.0
2	None	10.4	10.4	Limestone, 4000 lbs.	12.0	10.1	42.9
3	Kainit, 600 lbs.	30.4	32.4	Limestone, 4000 lbs.; Kainit, 1200 lbs.	49.6	47.3	159.7
4	Kainit, 600 lbs.; Acidulat'd bone, 350 lbs	30.3	33.3	Kainit, 1200 lbs.; Steamed bone, 395 lbs.	53.5	47.6	164.7
5	Potassium chlorid, 200 lbs.	31.2	33.9	Potassium chlorid, 400 lbs.	48.5	52.7	166.3
6	Sodium chlorid, 700 lbs.	11.1	13.1	None	24.0	22.1	70.3
7	Sodium chlorid, 700 lbs.	13.3	14.5	Kainit, 1200 lbs.	44.5	47.3	
8	Kainit, 600 lbs.	36.8	37.7	Kainit, 600 lbs.	44.0	46.0	164.5
9	Kainit, 300 lbs.	26.4	25.1	Kainit, 300 lbs.	41.5	32.9	125.9
10	None	14.9[1]	14.9	None	26.0	13.6	69.4

[1]Estimated from 1903; no yield was taken in 1902 because of a misunderstanding.

was early known as the Prairie Springs, and these springs were undoubtedly responsible for the formation.

The surface soil, 0 to 6⅔ inches, is black peat, generally well decomposed. About 60 percent of organic matter is present, or 300 tons per acre.

The subsurface is similar to the surface, but it is usually higher in organic matter.

The subsoil varies a great deal. In some cases the deeper subsoil passes into a drab clay. All strata frequently contain fragments of shells mixed with the organic matter.

Drainage is of first importance with this type. This in many cases is rather difficult to secure because tiles cannot be laid to good advantage in peat on account of irregular settling and the consequent displacement of the line. This difficulty may be partly overcome by placing the tiles upon boards laid in the bottom of the ditch, altho such a system cannot be regarded as permanent.

Where thoro drainage can be provided, either by the above method, by open ditches, or by laying tiles deep enough to secure a solid bed for them, very marked improvement can be made in the productive power of deep peat by the liberal use of potassium, which is by far the most deficient element.

In Table 17 are given results obtained from the Manito (Mason county) experiment field on deep peat, which was begun in 1902 and discontinued after 1905. The plots in this field were one acre[1] each in size, 2 rods wide and 80 rods long. Untreated half-rod division strips were left between the plots, which however were cropped the same as the plots.

The results of the four years' tests, as given in Table 17, are in complete harmony with the information furnished by the chemical composition of peat soil. Where potassium was applied, the yield was from three to four times as large as where nothing was applied. Where approximately equal money values of kainit and potassium chlorid were applied, slightly greater yields were obtained with the potassium chlorid, which, however, supplied about one-third more potassium than the kainit. On the other hand, either material furnished more potassium than was required by the crops produced.

[1]In 1904 the yields were taken from quarter-acre plots because of severe insect injury on the other parts of the field.

The use of 700 pounds of sodium chlorid (common salt) produced no appreciable increase over the best untreated plots, indicating that where potassium is itself actually deficient, salts of other elements cannot take its place.

Applications of 2 tons per acre of ground limestone produced no increase in the corn crops, either when applied alone or in combination with kainit, either the first year or the second.

Reducing the application of kainit from 600 to 300 pounds for each two-year period, reduced the yield of corn from 164.5 to 125.9 bushels. The two applications of 300 pounds of kainit (Plot 9) furnished 60 pounds of potassium for the four years, an amount sufficient for 84 bushels of corn (grain and stalks). Attention is called to the fact that this is practically the difference between the yield of Plot 9 (125.9 bushels) and the yield obtained from Plot 2 (42.9 bushels), the poorest untreated plot.

Farm manures and crop residues also contain sufficient potassium to make their use very effective on deep peat soil; and with prohibitive prices for commercial potash salts, farm manure, corn stalks, straw, etc., must be utilized for the improvement of such soils.

Medium Peat on Clay (1402)

One area of medium peat, 19 acres in extent, was found in Champaign county. The peat is about sixteen inches in depth, underlain by a black to drab clay. The surface soil contains 34 percent of organic matter, or 170 tons per acre.

If this type is not productive when well drained, it may be improved by extra deep plowing, by which process the more clayey material can be reached; otherwise the use of manure or commercial potassium is advised. (See treatment recommended for *Deep Peat.*)

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general soil-survey map of the entire state.

Other publications of general interest are:

Bulletins

76 Alfalfa on Illinois Soils
94 Nitrogen Bacteria and Legumes
115 Soil Improvement for the Worn Hill Lands of Illinois
125 Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois
181 Soil Moisture and Tillage for Corn
182 Potassium from the Soil
190 Soil Bacteria and Phosphates

Circulars

82 Physical Improvement of Soils
110 Ground Limestone for Acid Soils
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?
129 The Use of Commercial Fertilizers
149 Results of Scientific Soil Treatment: Methods and Results of Ten Years' Soil Investigation in Illinois
165 Shall We Use "Complete" Commercial Fertilizers in the Corn Belt?
167 The Illinois System of Permanent Fertility
181 How Not to Treat Illinois Soils
186 The Illinois System of Permanent Fertility from the Standpoint of the Practical Farmer: Phosphates and Honesty

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of ascertaining, and indicating on a map, the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of the work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with a plane table for determining directions of angling roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, ditches, streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is carried by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are: (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical composition of the different strata composing the soil, such as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

Tho common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprizing undecomposed and partially decayed vegetable or organic material	
	Mineral matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to 03 mm.
		Sand	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—Soils with 15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.

Mucks—Soils with 15 to 35 percent of partly decomposed organic matter mixed with much clay and silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and a little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel and much sand.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no direct agricultural value.

More or less organic matter is found in all the above groups.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which it is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and corn stalks.

[1]25 millimeters equal 1 inch.

The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cow-peas plowed under may have greater power to furnish or liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and land-owners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitrous acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish, or liberate, organic and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when composted with fresh farm manure; so that two tons of the compost[1] may be worth as much as two tons of manure. Bacterial action is also promoted by the presence of limestone.

[1]In his book, "Fertilizers," published in 1839, Cuthbert W. Johnson reported such compost to have been much used in England and to be valued as highly, "weight for weight, as farmyard dung."

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. Soils of cut-over or burnt-over timber lands sometimes contain so much partially decayed wood or charcoal as to destroy the value of the nitrogen-carbon ratio for the purpose indicated. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are *not* made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, alfalfa, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of wheat, corn, oats, and clover for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of general farm crops grown under normal conditions.)

To be sure, these are large yields, but shall we try to make possible the production of yields only a half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
Kind	Amount					
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2		2		
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244[1]	42	51	16	4
Total in four crops		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

on rich land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the ten years 1906 to 1915, a yield of 77 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 79 bushels per acre in live-stock farming (with limestone phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. On Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials which the farmer can utilize most profitably to bring about the liberation of plant food. The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms. Thus, in the conversion of sufficient organic nitrogen into nitrate nitrogen for a 100-bushel crop of corn, the nitrous acid formed is alone sufficient to convert seven times as much insoluble tricalcium phosphate into soluble monocalcium phosphate as would be required to supply the phosphorus for the same crop.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves it poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or on land being prepared for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land or returned after threshing (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn, (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

For the best production of seed in grain farming, alsike, sweet clover, or mammoth clover may well be grown. To avoid clover "sickness" it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease (such as cowpea wilt) these may alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires one pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages following.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently from one-half ton to one ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12 to 14 percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois has normally cost about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 to 12 cents a pound in steamed bone meal and acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 to 800 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought, as a rule.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and the nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. The mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The clover crop is an advantage to subsequent crops because of its deep-rooting characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly with other crop residues or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first twenty-four years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of sixty years (1852 to 1911), the yield of wheat was 12.7 bushels on untreated land and 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied. As further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the wheat crop removed annually an average of 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for sixty years (1852 to 1911) was 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus were applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels. Where only 70 pounds of sodium was applied in addition to the nitrogen and phosphorus, the average was 43.0 bushels. Thus, as an average of sixty years the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium on the wheat crop is becoming much more marked than that of sodium or magnesium; but this must be expected to occur in time where no potassium is returned in straw or manure and no provision made for liberating potassium from the supply still remaining in the soil.

If the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure is lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while in average live-stock farming the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) will permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field in Wayne county, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield included an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure was applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit, in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown by chemical analysis that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value, but its decomposition yields organic acids.

If we remember that, as an average, live-stock destroy two-thirds of the organic matter of the food they consume, it is easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, farmers following this practice ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium; and with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till,

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. Practically the same amount of calcium was found, by analyses, in the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone was applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 780 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every four or five years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

PHYSICAL IMPROVEMENT OF SOILS

In the management of most soil types, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Not only does it impart good tilth to the soil, but it prevents much loss by washing on rolling land, warms the soil by absorption of heat, retains moisture during drouth, and prevents the soil from running together badly; and as it decays it furnishes nitrogen for the crop and aids in the liberation of mineral plant food. This constituent must be supplied to the soil in every practical way, so that the amount may be maintained or even increased. It is being broken down during a large part of the year, and the nitrates produced are used for plant growth. This decomposition is necessary, but it is also quite necessary that the supply be maintained.

The physical effect of organic matter in the soil is to produce a granulation, or mellowness, very favorable for tillage and the development of plant roots. If continuous cropping takes place, accompanied with the removal or the destruction of the corn stalks and straw, the amount of organic matter is gradually diminished and a condition of poor tilth will ultimately follow. In many cases this already limits the crop yields. The remedy is to increase the organic-matter content by plowing under manure or crop residues, such as corn stalks, straw, and clover. Selling these products from the farm, burning them, or feeding them and not returning the manure, or allowing a very large part of the manure to be lost before it is returned to the land, all represent bad practice.

One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks. It is true that they decay rather slowly, but it is also true that their durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus. The nitrogen in a ton of corn stalks is 1½ times that in a ton of manure, and a ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as 4 tons of average farm manure; but when burned, both the humus-making material and the nitrogen which these stalks contain are destroyed and lost to the soil.

The objection is often raised that when stalks are plowed under they interfere very seriously in the cultivation of corn, and thus indirectly destroy a great deal of corn. If corn stalks are well cut up and then turned under to a depth of 5½ to 6 inches when the ground is plowed in the spring, very little trouble will result. Where corn follows corn, the stalks, if not needed for feeding purposes, should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or as manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except when manure can be brought back.

It must be remembered, however, that in the feeding of hay, or straw, or corn stalks, a great destruction of organic matter takes place, so that even if the fresh manure were returned to the soil, there would still be a loss of 50 to 70 percent owing to the destruction of organic matter by the animal. If manure is allowed to lie in the farmyard for a few weeks or months, there is an additional loss which amounts to from one-third to two-thirds of the manure recovered from the animal. Most of this loss occurs within the first three or four months, when fermentation, or "heating," is most active. To obtain the greatest value from the manure, it should be applied to the soil as soon as it is produced.

It is a common practice in the corn belt to pasture the corn stalks during the winter and often rather late in the spring after the frost is out of the ground. This tramping of stock sometimes puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing, and wetting and drying, with the aid of ordinary tillage, fail to produce good tilth before the crop is planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to result, and if put in oats, the soil is so compact as to be unfavorable for their growth. Sometimes the soil is worked when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the organic matter below the amount necessary to maintain good tilth.

PUBLICATIONS RELATING TO ILLINOIS SOIL INVESTIGATIONS

No. BULLETINS

76 Alfalfa on Illinois Soil. 1902 (5th edition, 1913)
*86 Climate of Illinois. 1903
*88 Soil Treatment for Wheat in Rotation, with Special Reference to Southern Illinois. 1903
*93 Soil Treatment for Peaty Swamp Lands, Including Reference to Sand and ''Alkali'' Soils. 1904 (See No. 157)
94 Nitrogen Bacteria and Legumes. 1904 (4th edition, 1912)
*99 Soil Treatment for the Lower Illinois Glaciation. 1905
*115 Soil Improvement for the Worn Hill Lands of Illinois. 1907
*123 The Fertility in Illinois Soils. 1908 (2d edition, 1911)
*125 Thirty Years of Crop Rotations on the Common Prairie Soil of Illinois. 1908
*145 Quantitative Relationships of Carbon, Phosphorus, and Nitrogen in Soils. 1910 (2d edition, 1912)
157 Peaty Swamp Lands; Sand and ''Alkali'' Soils. 1912
177 Radium as a Fertilizer. 1915
181 Soil Moisture and Tillage for Corn. 1915
182 Potassium from the Soil. 1915
190 Soil Bacteria and Phosphates. 1916
193 Summary of Illinois Soil Investigations. 1916
194 A New Limestone Tester. 1917
207 Washing of Soils and Methods of Prevention. 1918
208 Climate of Illinois. 1918

CIRCULARS

*64 Investigations of Illinois Soils. 1903
*68 Methods of Maintaining the Productive Capacity of Illinois Soils. 1903 (2d edition, 1905)
*70 Infected Alfalfa Soil. 1903
*72 Present Status of Soil Investigation. 1903 (2d edition, 1904)
*82 The Physical Improvement of Soils. 1904 (3d edition, 1912)
86 Science and Sense in the Inoculation of Legumes. 1905 (2d edition, 1913)
*87 Factors in Crop Production; Special Reference to Permanent Agriculture in Illinois. 1905
*96 Soil Improvement for the Illinois Corn Belt. 1905 (2d edition, 1906)
*97 Soil Treatment for Wheat on the Poorer Lands of the Illinois Wheat Belt. 1905
*99 The ''Gist'' of Four Years' Soil Investigations in the Illinois Wheat Belt. 1905
*100 The ''Gist'' of Four Years' Soil Investigations in the Illinois Corn Belt. 1905
*105 The Duty of Chemistry to Agriculture. 1906 (2d edition, 1913)
*108 Illinois Soils in Relation to Systems of Permanent Agriculture. 1907
109 Improvement of Upland Timber Soils of Illinois. 1907
110 Ground Limestone for Acid Soils. 1907 (3d edition, 1912)
*116 Phosphorus and Humus in Relation to Illinois Soils. 1908
*119 Washing of Soils and Methods of Prevention. 1908 (2d edition, 1912)
*122 Seven Years' Soil Investigation in Southern Illinois. 1908
123 The Status of Soil Fertility Investigations. 1908
*124 Chemical Principles of Soil Fertility. 1908
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils? 1909 (3d edition, 1912)
*129 The Use of Commercial Fertilizers. 1909
130 A Phosphate Problem for Illinois Land Owners. 1909
*141 Crop Rotation for Illinois Soils. 1910 (2d edition, 1913)
142 European Practice and American Theory Concerning Soil Fertility. 1910
145 The Story of a King and Queen. 1910
*149 Results of Scientific Soil Treatment; and Methods and Results of Ten Years' Soil Investigation in Illinois. 1911
150 Collecting and Testing Soil Samples. 1911 (2d edition, 1912)
155 Plant Food in Relation to Soil Fertility. 1912
*157 Soil Fertility: Illinois Conditions, Needs, and Future Prospects. 1912
165 Shall We Use ''Complete'' Commercial Fertilizers in the Corn Belt? 1912 (4th ed., 1913)
167 The Illinois System of Permanent Fertility 1913
168 Bread from Stones. 1913
181 How Not to Treat Illinois Soils. 1915
185 A Limestone Tester. 1916
186 I. The Illinois System of Soil Fertility from the Standpoint of the Practical Farmer. II. Phosphates and Honesty. 1916
193 Why Illinois Produces only Half a Crop. 1917
197 Essentials in Larger Food Production. 1917
208 Ten Wheat Yields in Egypt.
223 Sources of Fertilizing Materials for Illinois Farms. 1918
229 Illinois Wheat Yields with Nature's Fertilizers. 1918

SOIL REPORTS (BY COUNTIES)

1 Clay. 1911	6 Knox. 1913	11 Pike. 1915	16 DuPage. 1917
2 Moultrie. 1911	7 McDonough. 1913	12 Winnebago. 1916	17 Kane. 1917
3 Hardin. 1912	8 Bond. 1913	13 Kankakee. 1916	18 Champaign. 1918
4 Sangamon. 1912	9 Lake. 1915	14 Tazewell. 1916	
5 La Salle. 1913	10 McLean. 1915	15 Edgar. 1917	

*Out of print.

Sixteen Years' Results with Phosphorus on the University of Illinois Soil Experiment Field at Bloomington, on the Typical Prairie Land, of the Illinois Corn Belt

Year	Crops grown	Yield without phosphorus	Yield with phosphorus	Increase for phosphorus	Value of increase per acre
1902	Corn, bu.	37.0	41.7	4.7	$ 2.35
1903	Corn, bu.	60.3	73.0	12.7	6.35
1904	Oats, bu.	60.8	72.7	11.9	4.76
1905	Wheat, bu.	28.8	39.2	10.4	10.40
1906	Clover, tons	.58	1.65	1.07	10.70
1907	Corn, bu.	63.1	82.1	19.0	9.50
1908	Corn, bu.	35.3	47.5	12.2	6.10
1909	Oats, bu.	53.6	63.8	10.2	4.08
1910	Clover, tons	1.09	4.21	3.12	31.20
1911	Wheat, bu.	22.5	57.6	35.1	35.10
1912	Corn, bu.	47.9	74.5	26.6	13.30
1913	Corn, bu.	30.0	44.1	14.1	7.05
1914	Oats, bu.	40.6	45.0	4.4	1.76
1915	Soybeans, bu.	0.0	0.0	0.0	0.00
1916	Wheat, bu.	15.8	38.8	23.0	23.00
1917	Corn, bu.	19.2	44.0	24.8	12.40

Total value of increase in sixteen years	$178.05
Total cost of phosphorus in sixteen years	56.00
Net profit in sixteen years	$122.05

After the first year the phosphorus began to more than pay its annual cost; and during the second five-year period the increase produced by the phosphorus was worth almost as much as the total crops produced on the land not receiving phosphorus. In later years the need of organic manures with phosphorus has become apparent. (See pages 21 to 26 for more complete details.)

SOIL CONDITIONS IN NORTHEASTERN ILLINOIS

(Statement Supplementing the Soil Reports for the Counties Listed Below)

The soil maps of the counties in northeastern Illinois which were made from 23 to 45 years ago do not show the character of the glacial till underlying the soils in this region. This fact makes it necessary to interpret these maps in the light of more recent knowledge, since the agricultural value of the soils in this part of the state often is determined by the character of the underlying material.

The counties having soil maps which are defective in this respect are Champaign, Cook (unpublished), DuPage, Grundy, Kane, Kankakee, Lake, LaSalle, McHenry, McLean, Piatt, Will, and Woodford.

In addition to the counties listed, the following counties now have soil maps showing the areas where unfavorable underlying glacial till is present: Ford, Iroquois, Kendall, Livingston, Marshall, Putnam, and Vermilion.

The glacial tills in the northeastern part of Illinois vary from highly plastic, very slowly permeable material to loose, sandy, gravelly material which is porous and drouthy. The following tabulation shows the tills ranging in permeability to water from very slowly permeable to optimum or moderate permeability, but does not show the sandy, gravelly tills which occur less extensively than the slowly permeable tills. Only the dark-colored or prairie soils are listed, as they are more extensive than the light-colored or timber soils in all counties in this region except Lake and McHenry.

Clay till - Clarence-Rowe soils - very slowly permeable
Silty clay till - Swygert-Bryce soils - slowly permeable
Silty clay loam till - Elliott-Ashkum soils - moderately slowly permeable
Loam till - Saybrook-Lisbon soils - optimum permeability

On all soil maps published prior to 1930 the above-listed soils were for the most part shown as Brown Silt Loam and Black Clay Loam. The agricultural significance of the separations now being made is indicated by the following yields of hybrid corn on farms under good management for the period 1937 to 1944.

Clarence-Rowe	- average of	3	farms	- 51 bushels an acre
Swygert-Bryce	- " "	12	"	- 60 bushels an acre
Elliott-Ashkum	- " "	20	"	- 64 bushels an acre
Saybrook-Lisbon	- " "	20	"	- 76 bushels an acre

Further information about soil conditions in northeastern Illinois and in other parts of the state may be secured from the county farm advisers and from the Soil Survey, Department of Agronomy, Urbana.

Department of Agronomy
University of Illinois
Agricultural Experiment Station

1949

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